STATE LIBRARY OF PENNSYLVANIA
3 0144 00080856 8

CLASS ~~P38.58~~ BOOK ~~ldh~~

VOLUME 2 ~~1858~~

PY G345/1.1
1858
v.2

PENNSYLVANIA
STATE LIBRARY

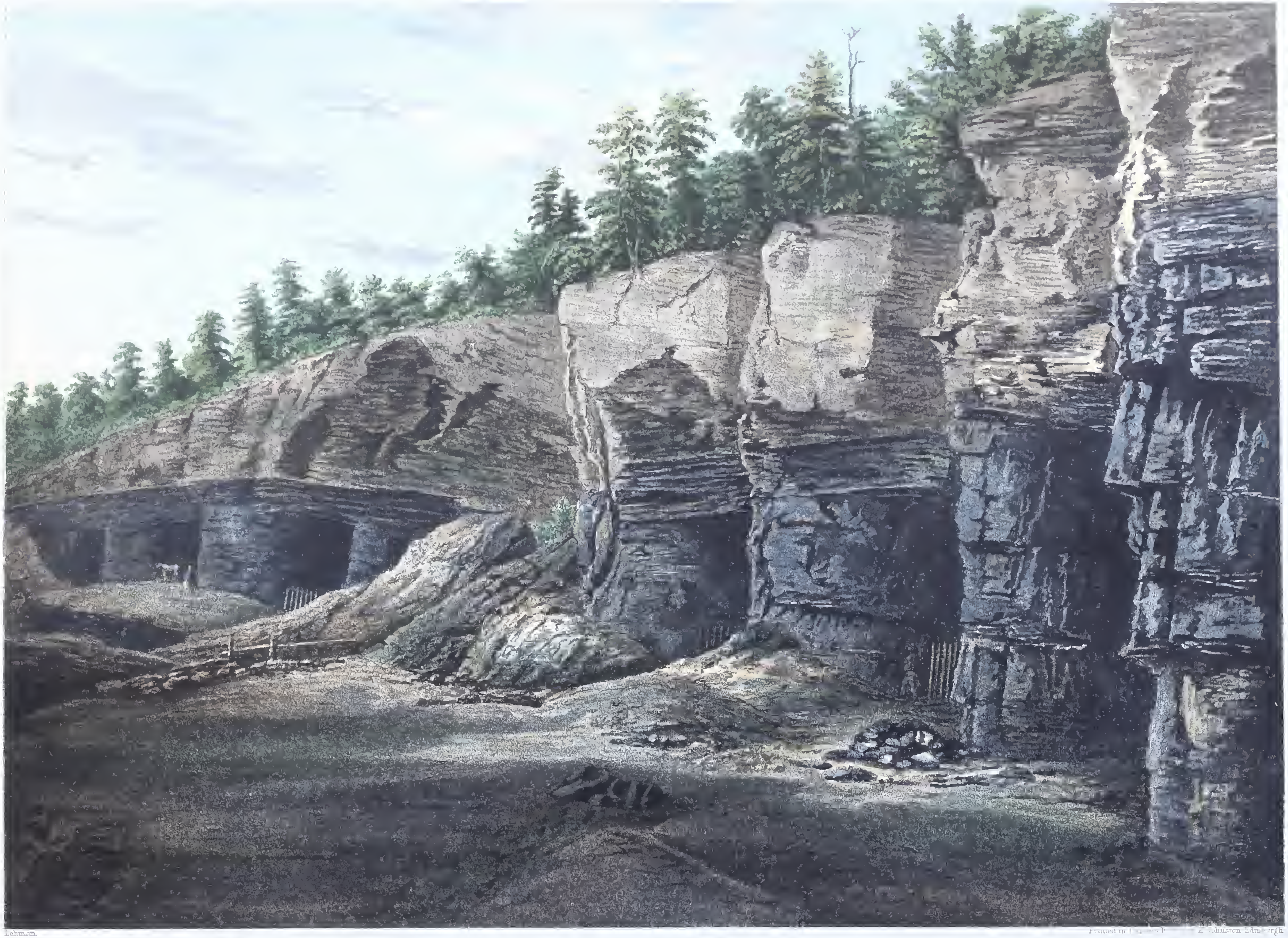
Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/geologyofpennsyl00penn_0

THE GEOLOGY

OF

PENNSYLVANIA



Lehman

Printed in [illegible] & Johnston Edinburgh

BALTIMORE COMP^{S} MINES, WILKES-BARRE.

THE
GEOLOGY
OF
PENNSYLVANIA

A GOVERNMENT SURVEY

BY

HENRY DARWIN ROGERS

STATE GEOLOGIST

PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF GLASGOW; HON. F.R.S.E., F.G.S.; MEMBER
OF THE AMERICAN PHILOSOPHICAL SOCIETY; FELLOW OF THE BOSTON ACADEMY OF ARTS
AND SCIENCES; MEMBER OF THE BOSTON NAT. HIST. SOCIETY, ETC. ETC.

IN TWO VOLUMES

VOL. II.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
MDCCCLVIII

Entered according to Act of Congress, in the year 1858, by
HENRY DARWIN ROGERS,
in the Office of the Clerk of the District Court of the United
States in and for the Eastern District of Pennsylvania.

P38.38
1.1r
1858 Vol.2

TABLE OF CONTENTS.

BOOK VIII.

EIGHTH PALÆOZOIC DISTRICT, OR ANTHRACITE COAL-BASINS, AND ENCIRCLING BELTS OF THE OLDER CARBONIFEROUS ROCKS.

INTRODUCTION.

PAGE
Position of the anthracite basins in the mountain-chain; limits and subdivisions of the district; strata, and their relations to the topography; classification of the Coal-measures, 1
General structure of the mountain-chain in its relations to the anthracite basins, 1
General limits of the anthracite district, 4
Natural leading subdivisions of the district, 5
Description of the strata, 7
Vespertine series around the anthracite basins, 8
Umbral red shale around the anthracite basins, 9
Geographical range of the Vespertine sandstone and Umbral red shale, 11
General view of the Seral series or coal strata of the State, 13
Composition of the coal strata, 13
Area and general distribution of the coal strata, 14
Limits of the Bituminous Coal-measures, 15
Classification of the coal-rocks, and their modifications of type, 16
1. The Seral conglomerate, 16
2. Lower Coal-measures, 17
3. Older coal-shales, or Lower Barren Group, 19
4. Upper or newer Coal-measures, 19
5. Upper or newer coal-shales, or Upper Barren Group, 20
Anthracitic coal strata, 20
1. Boundaries of the several coal-basins, 20
2. Composition of the Seral conglomerate in the special type which it presents in the anthracite region, 21

DIVISION I.

DETAILED DESCRIPTION OF THE SOUTHERN OR SCHUYLKILL BASIN.

CHAPTER I.

General structure and topography, 26
1. The Lehigh and Little Schuylkill District, 26
2. The Schuylkill and Swatara District, 26
3. The Mine Hill Basin or District, 27
4. The Wiconisco Basin, 27
5. The Dauphin Basin, 27
Undulations of the strata in the Southern Coal-field, 28
Classification and brief description of the anticlinal flexures or saddles, 28
Anticlinals from Mauch Chunk to Patterson and Mine Hill, 29
Anticlinals from Patterson and end of Mine Hill or Big Creek to East Norwegian Creek, 31
PAGE
Main group between Tuscarora and Mill Creek, 34
Anticlinals and basins between Mill Creek and West Norwegian, 38
Western series of flexures, 41

CHAPTER II.

First or Nesquehoning and Panther Creek division of the district between the Lehigh and Tuscarora, 47
Eastern end of the coal-field; estates of the Lehigh and Little Schuylkill Coal Companies, 48
Beginning of the coal strata, 48
Anticlinal axis A, or Rhume Run anticlinal, 50
A, Panther Creek south anticlinal, or subordinate axis of Panther Creek, 51
B, Summit Hill and Tamaqua anticlinal, 52
Synclinal belts or basins, 53
Basin A, or synclinal trough of anticlinal A and Locust Mountain, 53
Nesquehoning Mines, 54
Coal-seams of the Nesquehoning Mines, 57
Basins of Panther Creek Valley opposite Summit Hill, or basins *A*, *A a*, and *B*, 62
Locust Mountain basin *A*, 62
Basin *A a* (basin of the bed of Panther Creek), 62
Basin *B*, 63
Basin *B C*, or basin of the Lehigh Summit Mines, 63
Summit Mines of the Lehigh Company, basin *B C*, 63
Coals of Panther Creek basin and saddles, 67
Basin *D*, or basin of Sharp Mountain and anticlinal axis C, 68
The Coal-measures, under the several local types they present between the Lehigh and Little Schuylkill, 69
Of the positions in the general basin of the several groups and the more important individual coal-beds, 71
Coals of Summit Hill Basin, *B*, *C*, 71
Arrangements of the Lehigh Company for conveying the coal of Panther Creek and the Summit Mines to market, 71
Coal-schutes at Mauch Chunk, 73
The Mount Pisgah inclined plane, 74

CHAPTER III.

TAMAQUA.

Coals and Coal-measures, 76
Individual coal-seams, 77
Coals on the north side of the basin at the foot of Locust Mountain, 78
Synclinal axis of basin *B*, 80
Anticlinal axis B, 80
Synclinal axis of basin *D*, 80
Greenwood Tunnel, 83

L318975

CHAPTER IV.

THE SCHUYLKILL OR CENTRAL DISTRICT OF THE COAL-FIELD.

PAGE
- Introductory description, 84
- Anticlinals and basins between Tuscarora and East Norwegian, 85
  - Anticlinal D, or axis of South Mine Hill, 85
  - Coal-beds lifted by this axis, 86
  - Anticlinal E, or Casca William Diamond and Northern St Clair axis, 87
  - Of the basin *C D*, or that between the Main Mine Hill and the South Mine Hill, 87
  - Basin of anticlinals D and E, 88
  - Anticlinal F, the Patterson and St Clair axis, 88
  - Coals lifted by axis *F*, 89
  - The *D F* and *E F* basin, or that of Patterson and St Clair, 89
  - Subordinate anticlinals d and d d, 90
  - Axis G—anticlinal of the Silver Creek Switch-back Railroad and of South St Clair, 90
  - Basin *F G*, 91
  - Anticlinal H—that of Sillimanville and Mill Creek Furnace, 91
  - Coals lifted by axis H, 92
  - Basin *H F* and *H G*, 92
  - Peach Mountain synclinal belt, 92
- Peach Mountain anticlinals, 93
  - Anticlinal I, or main axis of Peach Mountain, 95
  - Anticlinal i, or southern subordinate saddle of Peach Mountain axis, 96

CHAPTER V.

- Southern coal-field between Tamaqua and Silver Creek, its anticlinals, basins, and collieries, 96
  - Anticlinal axis C, 96
  - Basin *D*.—Of the coal-beds, 97
- Second and third Tamaqua anticlinals and related basins, 97
  - Axis b, 97
  - Axis B, 98
- Basin *B*, Reinhardt's Run, Newkirk Tunnel, 98
  - Newkirk Tunnel, 98
  - Coals.—At Newkirk, 100
  - Collieries, 101
- Coals contained in basin C, on that of the Buckville and Palmer Tunnels, 102
  - Buckville, 102
  - Coals, 102
  - Palmer Tunnel, 103
- Tucker's Slope, basin *C*, 103
  - Coals, 103
  - Basin *C D*, or that of Tuscarora, 104
  - Slopes, 104
  - Whitfield Tunnels, De Long Tract, 105
- Of the flexures anticlinal and synclinal in the vicinity of Tuscarora, and the coals there developed, 105
  - Axis C, near Tuscarora, 105
  - Basin *C*, 106
  - Axis c and c c near Tuscarora, 107
  - Anticlinal c c c of Tuscarora, probably axis D, or that of the south ridge of Mine Hill, 107
  - The Short Saddle d, 108
  - Carter's Slope, 108
- Casca William, 108
  - Axis of Sinnickson's Slope, or Anticlinal D, 108
  - Coals in basin *D F*, on Casca William Creek, 109

PAGE
- Basin *D F*, from Sharp Mountain to Silver Creek, or Patterson Basin, 109
- Collieries and Coals—Sharp Mountain Colliery, 110
  - Beachem's Tunnels, 110
- Bushy Valley, 111
  - Meyer's Tunnels on Bushy, 112
  - The Luther or South Diamond Coal, 112
  - Basin *F H*, or that north of the Peach Mountain Basin, from Sharp Mountain to Silver Creek, 112
  - Basin *H I*, or Peach Mountain Basin—Sharp Mountain south of Patterson, 113
  - Milford Colliery, Peach Mountain Basin, Tunnel and Slope, 113
  - Peach Mountain Basin traced from Bushy Valley westward, 114
- Middleport Synclinal Belt, 114
  - Coals of the spurs east and south of the town, 115
  - Shaftings and Tunnel south-east of Middleport, 115
  - General Beckel's Tunnel, 115
  - Neville's Mine, south-east of Middleport, 115
  - Steinberger's Mines, half a mile south-west of Middleport, 116
- Coals at Middleport, 116
- Colahan's Gate Vein Colliery, 116
  - Section south of the Big Gate Coal, 117
- New Philadelphia, 118
  - Preston's Colliery (Neville and A. Lawton's), opposite New Philadelphia, 118
  - Lick Run, 118

CHAPTER VI.

- Coal-field between Silver Creek and Mill Creek, anticlinals, basins, and collieries, 119
  - Flexures on Silver Creek, 119
- Coals on Silver Creek, 120
- Anticlinal axes traced, 122
- Coal-seams above water-level in the several basins between Silver Creek and Mill Creek, 123
- Details of the several collieries between Silver Creek and Mill Creek, 125
  - Novelty Colliery, 125
- Cwmbola, Hubleyville, 125
  - Cwmbola Colliery, 125
  - Havener's (formerly), now Colahan's, 126
- Pinkerton's Tunnels, Bare Ridge (abandoned in 1853), 126
- Oliver's Colliery, south side of Bare Ridge (owned by Shippen and Whitaker), 127
- Zachariah's Run, 127
  - Eagle Hill Colliery, Zachariah's Run, 129
- Belmont (Five Points), 129
  - Lewis and Spohn Coal of Belmont, 129
  - Belmont Slope, 129
  - Ravensdale Tunnel, 130
- Crow Hollow, 131
- Mill Creek (above St Clair), 132
  - Structure east of Johns' Colliery, 132
  - Johns' New Slope, 132
- St Clair Mill Creek, 132
  - Milnes and Snyder's New Slope, 132
- McGinnis's New Slope north-east of St Clair (Carey's property), 133
  - Carey's Shaft, 133
- Boring in Crow Hollow in basin *F G*, on the estate of the North American Coal Company, 133

PAGE
Mill Creek, south of Carey's Shaft, 134
Upper red-ash coals of Mill Creek, 135
  Singley's Farm, 137
Mill Creek (southern part) Collieries, 138
Port Carbon, Mill Creek, 139
  Coal-seams in the Gate Ridge anticlinal flexure, 139

CHAPTER VII.

Coal-field between Mill Creek and the West Norwegian Valleys, 141
Anticlinal and synclinal flexures, and the coal-beds contained in each basin, 141
  Basin *D E* west, or that of Mount Laffy, 141
  Belt E G, 141
  Belt G H, 142
  Peach Mountain Basin, 142
  Basin *i J*, 143
  Basin *J K*, or that of West Norwegian, 143
  Basin *K*, or that of the Schuylkill at Pottsville, 144
Details of the several collieries and mining localities from Mill Creek to West Norwegian, 145
  Section on East Norwegian, 145
  Middle Norwegian, 146
  North American Company's Mines, 146
  West Norwegian, 147
  Brown's Colliery, 147
  Peach Mountain Coal of West Norwegian (Delaware Mines), 148
Sharp Mountain Coal-measures, Pottsville, 149
Coals in the north side of the Sharp Mountain Basin, 151
  Salem Colliery, Salem Hollow, east of Pottsville, 151

CHAPTER VIII.

Anticlinal flexures of the coal-field between West Norwegian and Swatara valleys traced in detail, with the coal-beds along their axes, 152
  Axis of Swatara Falls and Primrose Hill, or anticlinal M, 152
  Axis of the Dripping Arch and Phœnix Mines, or anticlinal N, 154
  Basin *M N*, south of Swatara Falls axis—part of Fisher's Basin, 155
Western Group of the subordinate anticlinals of the centre of the coal-field, between West Branch and Swatara, 157
  Peach Mountain Kantner axis, or anticlinal N, 157
  Minersville central axis, or anticlinal O, 158
  Minersville South or Peach Mountain inverting axis, or anticlinal O, 159
  Axis of West-West Branch, or anticlinal P, 160
  Griscom's axis, or anticlinal P, 161
  Llewellyn north axis, or anticlinal QQ, 161
  Branchdale Lewis Vein axis, or anticlinal P west, 162
  Llewellyn middle axis, or anticlinal Q, 162
  Axis of Big Lick Mountain, or anticlinal Q, 163
  Axis of Little Lick Mountain, or anticlinal R, 164
  Axis of Red Mountain, or Gate Ridge on anticlinal S, 166

CHAPTER IX.

Collieries between the West Norwegian and the Swatara, 168
Mine Hill Gap Colliery (John Doherty's), 168
  Dundas Colliery, No. 1 (about 400 yards west of Doherty's) 168
PAGE
  Minersville—basin *O o*, 169
  West Branch, 169
  Coals on the S. side of Mine Hill Gap—Basin *C E* west, 169
  Section of the Coal-measures in Sharp Mountain at the West Branch Gap, 170
  Collieries—Wolf Creek, 171
Anticlinal flexures and their coals on West-West Branch, 172
  Griscom's Axis and Mines, 172
  Red Mountain axis, 173
  Miller and Stahl's Phœnix Colliery, 174
  Llewellyn, 175
  Salem Colliery, below Llewellyn, 175
  Branchdale Colliery (McDonald's), Muddy Branch, 176
  Lower or Little Muddy Branch, Red Mountain axis, 177
  Bettinger's Mines, Little Muddy Creek, 177
  Coals on Swatara, 177
  Swatara Colliery (D. P. Brown & Co.), 178
  Middle Creek, 178

CHAPTER X.

Coal-field between Middle Creek and the forking of the basin, 179
Basin of Donaldson, or basin *N Q*, 180
  Thick Mountain Tunnel and Drifts, 181
  Basin of Big and Little Lick Mountains, or basin *Q R*; also Little Lick Mountain, 181
  Big Lick Mountain anticlinal, 182
  Coals in the gap of Big Lick Mountain, Donaldson, 182
  Little Lick Mountain, 183
  Basin of Little Lick Mountain and Red Mountain, 184
  Basin of Red Mountain anticlinal axis and Sharp Mountain, 185
  Red Mountain or Gate Range, 185
  Sharp Mountain Coals, their number and unusual position, 186

CHAPTER XI.

Wiconisco and Dauphin Basins, or the western branch basins of the Southern Coal-field, 188
Wiconisco, or Bear Valley Coal-basin, 189
  Klinger's Gap coal strata, 189
  Bear Gap, 191
The Dauphin Basin, 193
  Black Spring Gap, 195
  The Rausch Gap Section, 195
  Yellow Spring Gap Section, 196
  Rattling Run Gap, 197
  Big Flats, 198

CHAPTER XII.

Mine Hill Basin, and Mine Hill, 198
Structure of Mine Hill, 199
  Western Mine Hill, 200
Mine Hill Basin, its Structure, Coal-seams, and Collieries, 201
  Collieries and Coals of Mine Hill Valley, 202
  Lawton's Old Colliery Gap, 202
  Big Coal of Kelly's Hollow, 203
Mine Hill Valley, from Mine Hill Gap westward, 204
  Pine Knot Colliery, 204

PAGE
Lewis Dougherty's Colliery, east side of Mine Hill Gap, 205
Charles Hill's Colliery, west of Mine Hill Gap, 205
McGinnis's Hollow, 205
Coals at McGinnis's, 206
Dyer's Run, Sando's Colliery, about one mile west of McGinnis's, 206
Heckscherville Slope and Tunnel, 207
Thomastown Tunnel, 207
Oliver's Colliery, Peaked Mountain, 208
Meekesburg—Meeke's Western Tunnel, 208
Glen Carbon—Staunton's Tunnel—Dundas Tract, 208
Rohrersville—Rohrer's Mines, 209
Peaked Mountain and Buck Ridge anticlinal, and limit of Coal in Buck Ridge Basins north and south, 209
Buck Ridge and Peaked Mountain anticlinal, 210
Of the south-western branch of Mine Hill Basin, 211

CHAPTER XIII.

Description of the more important Coal-seams of the southern Coal-field, with the duplicate names which many of them bear, 212
Description of the several coals, 213
Synonyms of the coals having more than one name in the Pottsville Basin, 221
The Norwegian Valleys, 223
West Branch and Wolf Creek, 223
West-West Branch, 224
Mine Hill Valley, 224
Muddy Branch, 224

CHAPTER XIV.

Small coal-basins of Broad Mountain, 225
Broad Mountain, Mill Creek Basin, 225
Broad Mountain, Rattling Run Basin, 226

CHAPTER XV.

General classification of the Coal-measures of the Pottsville Basin, 226
Coal-measures on Little Schuylkill, 227
Coal-measures on Silver Creek, 227
Coal-measures on Mill Creek, 229
Coal-measures on West Branch and Wolf Creek, 230
Coal-measures in the Thick Mountain north of Donaldson, 231
Relation of the coal-beds of Mine Hill Valley to the White-ash Groups of the Main Pottsville Basin, 232

CHAPTER XVI.

Faults and slips of the strata, 234
Contortions, faults, and troubles, 235

DIVISION II.

EASTERN MIDDLE ANTHRACITE COAL-FIELD.

CHAPTER I.

General structure and topography, 239
Anticlinal belt No. 1, or that of Pismire Ridge, 239
Coal-basin No. 1, or that of Beaver Meadow, 240
Anticlinal belt No. 2, or that of Catawissa Ridge, 240
Coal-basin No. 2, 240
PAGE
Anticlinal No. 3, or that of Council Ridge and Little Tomhicken Valley, 241
Coal-basin No. 3, or that of Hazleton, 241
Anticlinal No. 4, or that of East Buck Mountain, Black Creek Ridge, and Racoon Valley, 242
Coal-basin No. 4, or that of Big Black Creek, 242
Anticlinal No. 5, or that of Conyngham Valley, 242
Coal-basin No. 5, or that of Little Black Creek and Main Black Creek, 243
Coal-basin No. 6, or that of East Green Mountain, 243
Coal-basin No. 7, or that of McCauley's Mountain, 243
Sugar-loaf Knob, 243

CHAPTER II.

The Beaver Meadow, or southern basin of the East Middle Coal-fields, or Coal-basin No. 1, 244
Anticlinal undulations of the Beaver Meadow Coal-field, 244
Eastern anticlinals of the Coal-field, 244
Anticlinal axis B, 245
Sub-basin A, or that of axes A B, 245
Anticlinal axis C, 245
Basin *b*, 246
Anticlinal axis D, 246
Basins of axes A to D, and of D, and of Main Axis No. 1, 246
Western anticlinals of the Beaver Meadow Coal-field, 246
Coal-measures on axis E, 247
Basin *c*, or that of South Beaver Creek, 248
Anticlinal axis F, or that of Jeanesville, 248
Basin C, or that of the York Company, and the Jeanesville South Slope Mine, 248
Extent of the Big Coal in the Middle Basin, 249
Jeanesville Slopes, 249
Jeanesville, 250
North Beaver Meadow Basin, or basin *g*, 251
Limits of the Big Coal in the North Beaver Meadow Basin, 251
Dreck Creek Coal-basin, or basin No. 2, 251

CHAPTER III.

The Hazleton Basin and its branches, or basin No. 3, 252
Anticlinals H and J, 252
Basin *h*, or No. 1 of the Buck Mountain Company's Lands, 252
Basin *i*, or No. 2 of the Buck Mountain Company, 253
Coal of the Buck Mountain Company's basins, 253
Basin *j*, or that of the Board Yard, 254
Basin *k*, 254
Anticlinal M, or that of Crystal Ridge, 254
Anticlinal N, or that of Cranberry Ridge, 254
Anticlinal O, or that of Tomhicken Ridge, 255
Basin N, or that of Big Tomhicken, 255
Basin O, or North Branch of the Hazleton Basin, 255
The Main Hazleton Coal-basin, 256
Hazleton, 257
Limits of the Main Coal-seam, and the collieries at present established on it in the Hazleton Basin, 259

CHAPTER IV.

Black Creek Basins, 260
Big Black Creek Basin, or basin No. 4, 260
Anticlinals P and Q, and basins *p*, *q*, and *r*, 261

PAGE
Anticlinals R, S, and T, and basins *s* and *t*, . . 261
Big Black Creek Basin, ... 261
Basin No. 5.—Little Black Creek Basin, . . 262
Basin of Main Black Creek, or basin No. 5 west, . 263
East Green Mountain basins, No. 6, . . 263
Basin No. 6, *y*, ... 264
Basin No. 7, or that of McCauley Mountain, . 264

DIVISION III.

WESTERN MIDDLE COAL-FIELD.

CHAPTER I.

MAHANOY COAL-REGION.

General structure and topography, ... 265
Mahanoy and Shamokin coal region, . . . 266
Detailed description of the anticlinal and synclinal flexures, ... 266
  Anticlinal of Head and Big Mountain, No. 1, . 267
  Coal-basins of Head and Big Mountain, Nos. 1 and 2, 267
  Bear Ridge anticlinal, and the south basin of the Mahanoy south of it, ... 268
  Coal-measures in Bear Ridge, ... 269
  Basin No. 3—the Mahanoy Basin proper, or the South Mahanoy Basin, ... 270
  Axis No. 4—Shenandoah axis, ... 271
  Basin No. 4, ... 271
  Anticlinal axis No. 5, or that of Ashland, . 272
Basins between the Mahanoy and Locust mountains, 272
  Basin No. 5, or Ashland Basin south of anticlinal No. 5, ... 272
  Basin No. 6, or that of the south side of Locust Mountain, ... 273
Coal-beds in the coal-field between the Mahanoy and Locust mountains, ... 274
  Mahanoy Gap, ... 274
  Flexures and coals on Big Mine Run, . . . 276
  Flexures and coals on Little Mine Run, . . 276
  Flexures and coals on Locust Run, and on the Catawissa Road, ... 277
Anticlinal flexures and intervening basins of the Shamokin Coal-field, with the coals which they present, 277
  Anticlinal No. 6—that of Locust Mountain, . 277
  Strata elevated to the surface by this anticlinal, . 278
  Anticlinal No. 7—that of Mine Ridge and of Mount Carmel, ... 278
  Strata exposed by denudation along this anticlinal, 279
  Synclinal valley or basin No. 7, being that between the Locust Mountain and Mount Carmel anticlinals, 280
  Subordinate anticlinal flexures in the Mount Carmel Basin, ... 281
  Of the several subordinate basins embraced in basin No. 7, or that of Mount Carmel, and of the coals contained in them, ... 283
  Of the narrow troughs in basin No. 7, west of Green Ridge Gap, ... 285
  Shamokin Basin, ... 285
  Coal Run Improvement and Railroad Company, . 285
  Locust Mountain Coal and Iron Company, . 286
  The Coal Mountain Coal Company, . . . 286
  Green Ridge Coal Company, ... 286
  Anticlinal No. 8, or that of Red Ridge, . . 287
  Coal-measures exposed by denudation along anticlinal No. 8, or that of Red Ridge, ... 288
  Of the Coal-measures exposed along axis A of basin 8, or that of Jamie's or Green Ridge, . . . 289
  Of the subordinate basins included in basin 8, . 291
  Anticlinal No. 9, or that of Coal Run Ridge, . 292
  Coal-measures exposed along the Coal Ridge anticlinal, 293
  Basin No. 9, or that of the north branch of Shamokin, 293
  Of the Coal-measures preserved in different parts of basin No. 9, ... 294
  Anticlinals in the prolongation of Basin 9, south of Shamokin, ... 295
  Basin No. 10, or that of Coal Run and its included anticlinals, ... 297
  Description of the Coal-measures in Coal Run Basin and at Shamokin Gap, ... 299
  Estimate of the coals in Coal Run Basin, . . 301

CHAPTER II.

Structure and contents of the coal-field between Shamokin Gap and the western extremity of the basin, 306
  Coal-beds on the Scott and Hunter tracts south of Carbon Run, ... 307
  Western end of the basin, or that watered by the east and west branches of Zerbe's Run, . . 308
  Coal-seams in the Zerbe's Run, or Trevorton District of the Shamokin Coal-field, ... 309
  Description of the individual coal-seams in the ascending order, ... 311

DIVISION IV.

NORTHERN ANTHRACITE COAL-FIELD, OR BASIN OF THE LACKAWANNA AND NORTH BRANCH OF THE SUSQUEHANNA.

CHAPTER I.

Topographical features, composition of the strata, and general structure of the basin, . . . 318
  Form and interior features of the valley, . . 318
  General view of the strata, ... 319
  General structure of the basin, ... 323
  Undulations of the basin, ... 324
  The Coal-measures, ... 328
  Subdivisions of the coal-field, ... 329

CHAPTER II.

Carbondale and Archbald district, ... 330
  Valley north-east of Carbondale, ... 330
  Of the Lackawanna Basin, from Carbondale southward, ... 331
  Archbald, ... 334
  Jessup, ... 335

CHAPTER III.

Coal-measures of the Scranton District of the Lackawanna Basin, ... 338
The individual coal-beds, and the strata which separate them, ... 338
Undulations of the strata in the Scranton District of the Lackawanna Coal-basin, and the distribution of the several Coal-seams in their local basins, . . 342
  Positions and distribution of the several coal-seams, 345
  Coals in the basin south of axis No. 2, . . 345
  Coal B, Roaring Brook Basin, ... 346

PAGE
Coal D, Roaring Brook Basin, 347
Coal E, Roaring Brook Basin, 347
Coal F, Roaring Brook Basin, 347
Of the Roaring Brook Basin west of the Lackawanna, 348
Coals in the Scranton Basin, or that between axis No. 2 and axis No. 4, 351
Basin of Pine Brook and the Lackawanna, 352
Basin of the Diamond Mines, 352
Road between Hyde Park and Pittston, 355
From Spring Brook towards Scranton *via* the south road, 356
Strata exposed on the Pennsylvania Company's Loaded Track railroad from Pittston towards Scranton, 357
Iron ores of the vicinity of Scranton, 357
Iron ores of the Coal-measures, 358
Other iron ores smelted at Scranton, 359
Roaring Brook Falls, 360
Absence of coal in Spring Brook Valley, south of the Loaded Track, 360

CHAPTER IV.

THE PITTSTON AND MILL CREEK DISTRICT.

General section of the Pittston and Port-Griffith Coal-measures, 361
Axis VI., or that of Morgan's Mine, 361
Strata lifted by axis VII., 362
Axis VIII., or that of the Iron Foundry, 362
Axis IX., 363
Strata lifted to the surface by axis IX., 364
Axis X., or that of Plainville, 365
Basin X., or that north of axis X., 366
Axis XI., 367
Axis XII., or that of Bennett's Big Coal, 367
Axis XIII., 368
Axis XIV., or that of Miner's Mill, 369
Axis XV., or that south of Gardiner's Creek, 369
Axis XVI., or that of the New Haven Mine, 370
Works of the Pennsylvania Coal Company at Pittston, 371
New mines of the Pennsylvania Coal Company, 373
Port Griffith, 373
Coal-mines traced from Wilcox's north-east towards Pittston, 374
Plainsville, 375

CHAPTER V.

Wilkesbarre, Nanticoke, and Shickshinny district, 376
Synclinal belt or general basin XVII., 376
Position of the main synclinal axis of the river-basin, 379
Coal-measures contained in the river-basin west of Wilkesbarre, 380
Anticlinal belt XVII., 381
The Great Baltimore Bed, 381
Basin XVIII. and its undulations, 384
Anticlinals included in basin 18, 385
Anticlinal range XIX., 389
Basin 19, or that of the north foot of the Little Mountain, 390
Distribution of the coal in the east end of basin 19, 393
Coals in Solomon's Gap, 394
District west of Solomon's Gap, 395
Iron ores, Lee's Mines, Nanticoke, 399
From Nanticoke westward, 399
PAGE
The Hog-back, 401
Coal-basin west of the Susquehanna, 404
Iron ores, 404

CHAPTER VI.

Wyoming, Kingston, and Plymouth District, 405
Monoclinal south-dipping belt of strata between the Pittston Gap and Hertzoff's Hollow, 405
Of the coal-beds hitherto discovered in this belt, 406
Iron ores, 407
The Plymouth Belt, or that extending from Kingston to Nanticoke Notch, 407
Coal-measures and workable coal-seams of the Plymouth District, 409
1st, The Plymouth Great Bed, 409
2d, Bennett's or Patton's Coal-bed, 410
3d, The Cooper or Orchard Bed, 410
4th, The Gould Coal-bed, 411
Outcrops of the coals, 412

APPENDIX TO BOOK VIII.

BEING A REVISION OF PORTIONS OF THE SOUTHERN ANTHRACITE COAL-FIELD.

Tuscarora, 413
Middleport, 414
Casca William Valley, 415
Silver Creek, 417
Zachariah's Run, 419
East Ravensdale, 419
Crow Hollow, 420
Mill Creek, 420
East Norwegian, 424
West Norwegian, 424
West Branch, 426
Minersville, 428
Wolf Creek, 429
West-West Branch, 431
Muddy Branch, 434
Swatara, 436
Middle Creek, 438
Donaldson, 438
Rausch Creek, 439
Bear Gap, 440
Mine-Hill Valley, 442

BOOK VIII.—(*Continued*).

Broad-Top Coal-field, 448
Boundaries of the Broad-Top Coal-field, 448
Area of coal, 449
North Wray's Hill, 449
Shoup's Run, 453
Six-mile Run, 455
Round Knob, 459
Sandy Run, 461
Kimber's Run, 463
Iron ores, 464
Areas of the coal-basins of Pennsylvania, 465

PAGE

BOOK IX.

NINTH PALÆOZOIC DISTRICT, OR BITUMINOUS COAL-FIELDS AND THEIR ASSOCIATED OLDER CARBONIFEROUS STRATA.

DIVISION I.

VESPERTINE AND UMBRAL SERIES IN THE BITUMINOUS COAL REGION OF PENNSYLVANIA.

Topographical relations of the Vespertine and Umbral series, 466

CHAPTER I.

Vespertine conglomerate—geographical distribution, 467
Modifications in the type and thickness of the Vespertine sandstone in the bituminous coal region, 467

CHAPTER II.

Umbral red shale—geographical distribution, 468
Modifications in the type and thickness of the Umbral red shale in the bituminous coal region, 469

DIVISION II.

GENERAL VIEW OF THE BITUMINOUS COAL STRATA.

INTRODUCTORY CHAPTER.

Stratigraphical arrangement of the Coal-measures of Western Pennsylvania, 474
A general vertical section of the bituminous coal strata of Pennsylvania, 474
General description of the several bituminous coal-basins, 477
The anticlinal axes and their intervening coal-basins, 479

SUBDIVISION I.

Bituminous coal-basins north of the Conemaugh and Ohio, 480

CHAPTER I.

First Basin and principal axis north-west of the Alleghany Mountain, 480

CHAPTER II.

Second Basin and axis north-west of the Alleghany Mountain, 482
Second coal-basin, Towanda Mountain, 482
Towanda Coal-field, 482
The Lycoming or Ralston Coal-field, 482

CHAPTER III.

Third Basin and anticlinal axis, 483

CHAPTER IV.

The Fourth Basin and anticlinal axis, 485

CHAPTER V.

Fifth Basin and anticlinal axis, 486
Coal-beds of the Fifth Basin, 487

PAGE

CHAPTER VI.

The Sixth Coal-basin, and final outcrop on the north-west, 488
Coal-measures of the Sixth Basin, Tionesta group, 489
Sharon Group, 489
Clarion Group, 490
The Brookville Coal, 490
Clarion Coal and Ferriferous Limestone, 490
The Scrubgrass Coal-bed, 491
Kittanning Coal-bed, 491
The Freeport Group, 492
The Lower Freeport Coal, 492
The Freeport Limestone, 492
Upper Freeport Coal, 493
The Barren Group, 493
The rest of the Barren measures, 493

SUBDIVISION II.

Bituminous coal-basins south of the Conemaugh and Ohio, 493

CHAPTER I.

The First Coal-basin and its subdivisions, or the synclinal belt between the Alleghany Mountain and Laurel Hill, 494
The first or Salisbury subdivision, 494
The second or Stoyestown subdivision, 495
The third or Johnstown subdivision, 496

CHAPTER II.

The Second Coal-basin, or Ligonier Valley, 497

CHAPTER III.

The Third Basin and its subdivisions, being the region west of Chestnut Ridge, and south of the Conemaugh and Ohio, 499
First subdivision of the Third Basin, 500
Lower or Clarion and Freeport Group, 501
Middle or Barren Group, 502
The Upper or Greene County Group, 503
The Pittsburg Coal-bed, 503
The Redstone Coal, 505
The Sewickly Coal, 505
The Great Limestone Bed, 505
The Uniontown Coal, 506
The Waynesburg Coal-bed, 506

SUBDIVISION III.

Detailed description of the bituminous coal region, 507

CHAPTER I.

The First Basin westward to Pine Creek, 507

CHAPTER II.

Second Bituminous Coal-basin westward to Pine Creek, 511
Towanda Coal-basin, 513
Ralston, 513
Cartersville, 517
Blossburg, 519

PAGE

CHAPTER III.

The Third Coal-basin westward to Pine Creek, . 519

CHAPTER IV.

The Fourth Basin westward to Pine Creek, . . 524
Cowanesque, ... 525

CHAPTER V.

The Fifth Coal-basin west to the Genesee River, . 525

CHAPTER VI.

Country between Pine Creek and the Susquehanna waters, ... 526

CHAPTER VII.

First Basin traced from the Susquehanna south to Cambria County, ... 527
Tangascootac, ... 529
Philipsburg, ... 531

CHAPTER VIII.

Second Basin traced from the Susquehanna south-west into Cambria County, ... 533
Karthaus, ... 535
Clearfield Creek, ... 537

CHAPTER IX.

Third Basin from the Sinnemahoning southward into Indiana County, ... 538
Bennett's Branch, ... 539

CHAPTER X.

The Fourth Basin south-westward into Jefferson County, 540
Brandycamp, ... 543
Luthersburg, ... 545

CHAPTER XI.

Fifth and Sixth Basins in Potter, McKean, Elk, and Forest counties, ... 546
Limestone, ... 548
Bog iron-ore, ... 549
Clarion River, ... 553

CHAPTER XII.

The Sixth Basin south-westward, ... 553
Tunamaguont, ... 555
Alleghany River near Warren, ... 557
Seral Conglomerate, north-west limit, . . 557
Tionesta Coal Group, north-western limit, . . 558
North-western limit of the Sixth Basin, from French Creek westward to the Ohio line, . . . 558
West of the Shenango River, ... 560

CHAPTER XIII.

The North-western side of the Sixth Basin—*Continued*, 561
The Tionesta Coal, from Franklin westward, . 561
Upper and Lower Porter coals, ... 563

CHAPTER XIV.

North-western border of the Sixth Basin—*Continued*, 564
Mercer and the Beaver River, ... 564
Mercer, ... 565

CHAPTER XV.

Sixth Basin in Jefferson and Clarion counties; Coal-beds above the Tionesta Sandstone, ... 567
The Clarion Coal-bed, ... 567
Bog iron-ore, ... 568
The buhrstone or chert, ... 568
Clarion, ... 569
Western side of the Clarion, ... 570

CHAPTER XVI.

Sixth Basin; south-east-dipping Clarion Group; region west of the Alleghany River, ... 572
South-east-dipping Clarion Group, ... 575

CHAPTER XVII.

Sixth Basin west of the Alleghany River—Freeport Group, 576
Freeport Group, ... 577
Sugar Creek Section, Great Western Furnace, . . 577

CHAPTER XVIII.

Freeport Group, Sixth Basin, and country west of the Beaver River, ... 580
Lower Freeport Coal, ... 582
The Kittanning Coal-bed, ... 582
The Ferriferous Limestone, ... 582

CHAPTER XIX.

Country watered by the Red Bank Creek, Jefferson County—Fifth Basin, ... 583
Red Bank Creek, ... 585

CHAPTER XX.

Country on the Mahoning and Cowanshannock waters, Third and Fourth Basins, Indiana and Armstrong counties, ... 586
Third and Fourth Basins, ... 587

CHAPTER XXI.

Third Basin, in Indiana County, ... 589
Black-Lick and Crooked Creeks, ... 589
Crooked and Plum Creeks, ... 591

CHAPTER XXII.

Fourth and Fifth Basins—Kittanning and Freeport—Crooked Creek and the Kiskiminetas, . . 592
Kittanning, ... 593
Freeport, ... 595
Leechburg and Warren, ... 597
Saltzburg, ... 599

CHAPTER XXIII.

Third Basin—First Subdivision, along the Conemaugh: Lower and Middle Coal-measures, . . . 599

PAGE

CHAPTER XXIV.

1. Lower rocks of the First Sub-basin, of the Third Basin, between the Loyalhanna and the Conemaugh, along the base of Chestnut Ridge, 603
   Coal-beds of Loyalhanna Creek, 603
2. Lower rocks south of the Loyalhanna, along Chestnut Ridge, 604
   Coal-beds on the Big Sewickly, First Sub-basin and Axis, 604
3. Third Basin, First Subdivision, along Jacob's Creek, 607
   Jacob's Creek, 607
4. Jacob's Creek in the Second Sub-basin, 608
5. Lower Coals and Barren measures along Mount's Creek, 609
   Youghiogheny, 611
6. Lower rocks southward of the Youghiogheny, 612
   West base of Chestnut Ridge, 615

CHAPTER XXV.

1. Pittsburg Coal-bed, and the rocks above it, in the Third Basin south of the Conemaugh, 616
2. Pittsburg Coal, south of the Loyalhanna—First Sub-basin, 617
3. The Pittsburg Coal-bed southward of the Sewickly, 618
4. Rocks above the Pittsburg Coal, south of the Sewickly Creek, in the First Subdivision of the Third Basin, 619
5. Pittsburg Coal, south of Jacob's Creek, 620
6. Pittsburg Coal, south of Youghiogheny River, 622
7. Rocks above the Pittsburg Coal, south of the Youghiogheny River, 623
8. Pittsburg Coal, and strata overlying it, along the Redstone Creek, and southward, 624
9. Pittsburg Coal-bed south-westward from Redstone Creek, 625
10. Pittsburg Seam, upon the First Sub-axis, between Redstone Creek and George's Creek, 626
11. Rocks above the Pittsburg Coal, south of Redstone Creek, 628

CHAPTER XXVI.

1. Second subdivision of the Third Coal-basin west of the First Sub-axis south of the Conemaugh — upper group, 628
2. Rocks above the Pittsburg Coal-bed, Second Subdivision of Third Basin, 629

CHAPTER XXVII.

Alleghany and Monongahela Rivers, in the neighbourhood of Pittsburg, 630
   Black fossiliferous limestone, 631
   Grey sandstone, 632
   Barren measures, 633
   Pittsburg Limestone, 634
   Pittsburg Coal, 634
   The Great Limestone, 635

CHAPTER XXVIII.

Third Subdivision of the Third Great Basin south of the Greensburg and Pittsburg Turnpike, 636
   From M^cKeesport to Robbstown (West Newton), along the Youghiogheny River, 637
   Perryopolis, 639

PAGE

Rocks above the Pittsburg Coal, west of the Second Sub-axis, and south of the Pittsburg and Greensburg Turnpike, 640
   Williamsport, 641
   Brownsville, 643
   Upon the road from Brownsville to Uniontown, 644

CHAPTER XXIX.

Country south of the Conemaugh, in the First and Second Basins, in Somerset and Fayette counties, 650
   First or Salzburg subdivision of the First Basin, 650
   Second and third divisions of the First Basin, 652
   Johnstown, 653
   Stony Creek and Paint Creek, 655
   Laurel Hill Creek, 657
   Castleman's River, 659
Second Basin, 660
   Lockport, 661
   Indian Creek, 663

CHAPTER XXX.

Of the thin group of coal strata between the Umbral red shale and the main Seral conglomerate, in Somerset and Fayette counties, 665

PART III.

MESOZOIC RED SANDSTONE SERIES.

INTRODUCTORY CHAPTER.

Geographical limits of the Mesozoic red sandstone, 667
Composition of the Mesozoic red sandstone, 669
Of the dip of the strata, 670
Igneous rocks of the Mesozoic red sandstone, 671

CHAPTER I.

Detailed description of the Members of the Mesozoic series, 672
   Red shale and sandstone, 672
   Boundary of the Mesozoic red sandstone in the Chester County lead-mining district, 675
   Of the red shale and sandstone in York and Adams counties, 677
   Section along the west side of the Susquehanna, 677

CHAPTER II.

Lower calcareous conglomerate west of the Susquehanna, 679

CHAPTER III.

Upper calcareous conglomerate, 681
   Upper calcareous conglomerate south-west of the Susquehanna, 682

CHAPTER IV.

Trap-dykes of the Mesozoic belt, and alterations produced in the strata in contact with them, 684
   Trap-dykes west of the Susquehanna, 687
Organic remains and geological age, 692
   Question of age, 693
Red sandstone of the Connecticut Valley, 694

PAGE
Organic remains of the main red sandstone belt of the Atlantic slope, 695
Fossils of the Mesozoic belts of Virginia and North Carolina, 696

PART IV.

IGNEOUS ROCKS AND MINERALS, VEINS AND ORES.

Mineral veins of the Pickering Creek Valley, near Phœnixville, 699
Geological relations of the mineral veins, 699
The Wheatley Lode and its mines, 701
Trap-dykes of the Wheatley Lode, 702
The trap-dykes in the Wheatley Lode, 703
Extent and condition of the Wheatley Mine in 1853, 703
Product of the mine in ore, 704
Branches from the main lode in the Wheatley Mine, 704
The present extent of the Brookdale Mine, 705
Mineral veins and metalliferous deposits of the gneissic region north of the Chester County Valley, 706
Granitic and trappean dykes, 706
Prevailing direction of the granite dykes, 706
Trap-dykes, 706
Metalliferous veins, 706
Knauertown iron and copper veins, 706
Elizabeth Copper Mine, 707
Steel's Iron-ore Pits, 707
Hopewell Furnace Ore-pits, 707
Warwick Iron Mines, 707
Leighton Iron-ore Mine, 707
Warwick Iron Mine proper, 708
Knauertown Iron Mine, 709
Other mineral veins in the northern gneissic district, 709
Old Copper Mine, on Copper Mine Run, in Bath township, in Lancaster County, 709
Localities of well-characterised crystalline minerals within the gneissic districts of Pennsylvania, 709
Minerals in the southern gneissic district, 709
Minerals in the middle gneissic district occurring in the genuine or older gneiss, 710
Minerals of the northern gneissic district, or of the South Mountains and their spurs between the Delaware and Schuylkill, 710
Minerals of the metamorphic Primal strata, and of the middle range of the southern gneissic district, possibly the same formation under more extreme metamorphism, 710
Altered Primal slates, 711
Localities of minerals associated with the Auroral limestone, 712
Southern metamorphic district, 712
Middle metamorphic district, 712
Northern metamorphic district, or South Mountains, 712

ON THE IRON ORES OF THE GNEISSIC AND PALÆOZOIC FORMATIONS OF PENNSYLVANIA.

Introductory Remarks, 712

CHAPTER I.

Of the iron ores of the metamorphic or gneissic rocks, 713
Magnetic iron-ore, or oxidulated iron, 713
Metalliferous veins of the South Mountains, 715
PAGE
Iron ores of the gneiss, 715
Iron mines of the Lehigh Hill, 715
Durham Iron Mine, 715
Mount Pleasant Iron Mines, 715
Penn's Mount Ore-vein, 716
Analysis of iron ores of the Gneissic rocks of Pennsylvania, 717

CHAPTER II.

Iron ores of the Primal series, 718
Cornwall Iron Mines, 718
Surface iron-ores of the Primal series, 720
Analyses of specimens of hydrous peroxide of iron of the Primal slates, Pennsylvania, 721

CHAPTER III.

Iron ores of the Auroral and Matinal series, 722
Iron ores and mines of the Kittatinny Valley, 722
1. Of the district between the Delaware and Lehigh rivers, 722
2. Of the district between the Lehigh and Schuylkill rivers, 723
Analyses of specimens of hydrous peroxide of iron, or hæmatite, of the Auroral Limestone, Pennsylvania, 727
Table of hæmatite iron-ores of the Auroral Limestone —*continued*, 728
Table of analyses of iron-ores of the Matinal slates, Pennsylvania, 728

CHAPTER IV.

Iron ores of the Surgent series, 729
Analyses of specimens of iron ore of the Surgent series, Pennsylvania, 731

CHAPTER V.

Iron ores of the Pre-meridian and Meridian series, 731
Table of analyses of iron ores of the Pre-meridian series, 732

CHAPTER VI.

Iron ores of the Cadent and Vergent series, 732
Table of analyses of iron ores of the Cadent and Vergent strata of Pennsylvania, 733

CHAPTER VII.

Iron ores of the Umbral series, 734
Analyses of iron ores of the Umbral red shales of Pennsylvania, 734

CHAPTER VIII.

Iron ores of the coal strata, 735
On the origin and accumulation of the proto-carbonate of iron in Coal-measures, &c., 737
Analyses of the carbonates of iron of the Coal-measures of Pennsylvania, 739

SKETCH OF THE GEOLOGY OF THE UNITED STATES.

Hypozoic and Azoic metamorphic rocks, 744
Gneissic rocks, 744
Description of the rocks, 744
Semi-metamorphic or Azoic strata, 744
Metamorphic Palæozoic strata, 745

PAGE
Geographical distribution, ... 746
Minerals, ... 748
Palæozoic formations, ... 748
Primal series, or Potsdam sandstone of New York, 751
Auroral series, or Black River, and Chazy limestone and Calciferous sandstone of New York, . 752
Matinal series, or Trenton limestone and Hudson River slate group of New York, . . . 752
Levant series, or Medina Group of New York, . 753
Surgent series, or Clinton Group of New York, . 753
Scalent series, or Onondago Salt and Niagara Limestone Groups of New York, . . . 754
Pre-meridian series, or Lower Helderberg limestone of New York, ... 754
Meridian series, or Oriskany sandstone of New York, 755
Post-meridian series, or Upper Helderberg limestone of New York, ... 755
Cadent series, or Genessee, Hamilton, and Marcellus Groups of New York, ... 755
Vergent series, or Chemung and Portage Groups of New York, ... 756
Ponent series, or Catskill Group of New York, . 756
Vespertine series, or lower Carboniferous strata, . 756
Umbral series, or middle Carboniferous strata, . 757
Seral series, or Coal-measures, . . . 758
Upper Coal-measures; supposed Permian formation, 759
Mesozoic formations, or middle secondary strata, . 759
Mesozoic red sandstone, ... 760
Organic remains and geological age, . . 760
Dip of the red sandstone, and physical conditions attending its origin, ... 761
Trap-rocks, ... 763
Metalliferous veins, ... 763
Jurassic coal-formation, ... 763
Oolitic Basin, North Carolina, ... 764
Newer Mesozoic, ... 765
Cretaceous deposits, ... 765
Geographical distribution, ... 765
Organic remains and equivalents, . . . 766
Physical Geography of the Cretaceous era, . 767
Cainozoic or Tertiary formations, . . . 767
Atlantic Belt, ... 767
Pacific Slope, ... 767
Central Tertiary tracts, ... 768
Eocene formations, Atlantic Slope, . . . 768
Description of Eocene strata, . . . 769
Fossils and geological equivalents, . . . 769
Physical geography of the Eocene, . . . 770
Miocene strata of the United States, . . . 770
Miocene on the Atlantic, ... 770
Pacific Belt, ... 770
Miocene strata of the central and western parts of the Continent, ... 771
Fossils and equivalents of the Miocene, . . 771
Nebraska Basin, ... 771
Miocene fresh-water basin of the Niobrara and White Rivers, ... 772
Pliocene and Pleistocene strata, ... 772
Pliocene and Pleistocene beds of Virginia and North Carolina, ... 772
Pliocene strata of Nebraska, ... 773
Californian Pleistocene beds, ... 773
Fossils of the Atlantic Pleistocene strata, . . 773
The northern Pleistocene, or great Boulder-drift, . 774
PAGE
Southern limit of the Drift, . . . 774
Striated rocky floor of the Drift, . . . 774
Pleistocene fossiliferous clays and sands, . . 775
Fresh-water Pleistocene of the Western States, . 775
Later local drift, ... 775

CONDITIONS OF THE PHYSICAL GEOGRAPHY ATTENDING THE PRODUCTION OF THE PALÆOZOIC STRATA OF THE UNITED STATES.

Sources of the sedimentary matter—state of the waters—changes of level of the sea-bottom—horizons of continuity and discontinuity, . . . 776
Preliminary considerations, ... 776
Horizons of continuity and discontinuity, . . 777
Depositions and disturbances of the Primal period, 779
Depositions and disturbances of the Auroral period, 781
Auroral blue limestone, Chazy and Black River limestone of New York, ... 782
Disturbances of the crust at the end of the Auroral period, ... 783
Palæontological break between the Auroral and Matinal series, ... 783
Depositions and disturbances of the Matinal period, 783
Stupendous crust-movement and revolution in the earth's inhabitants at the close of the Matinal period, ... 784
Palæontological break at the end of the Matinal period, ... 788
Deposition and disturbances of the Levant period, 788
Deposition and disturbances of the Surgent series, 789
Deposition and disturbances of the Scalent series, 789
Deposition and disturbances of the Pre-meridian series, ... 790
Deposition and disturbances of the Meridian series, 790
Deposition and disturbances of the Post-meridian series, ... 791
Depositions and disturbances of the Cadent series, 791
Depositions and disturbances of the Vergent series, 792
Depositions and disturbances of the Ponent series, 793
Depositions and disturbances of the Vespertine series, 793
Depositions and disturbances of the Umbral series, 794
Of the limits of the Appalachian Coal strata, . 795
Nature of the Coal strata, ... 796
Of the phenomena connected with the Coal-seams, 799
Of the intimate mechanical structure of the Coal, . 800
Of the character of the strata in immediate contact with the Coal-seams, ... 802
Of the roof of the Coal, ... 803
Of the direct contact of coal-beds and marine limestones, ... 804
Theory of the origin of the Coal strata, . . 805
Gradation in the proportion of volatile matter in the Coal of the Appalachian Basins, . . . 808
Fossils of the Coal-formation, ... 810
Of the formative actions concerned in the production of the Palæozoic and other strata, . . . 811
Perpendicular deposition, ... 812
Stratification without suspension, . . . 812
Stratification from a state of suspension in water, 813

ORGANIC REMAINS OF THE PALÆOZOIC STRATA OF PENNSYLVANIA.

Fossils of the Primal strata, ... 815
Organic remains of the Auroral strata, . . 817

PAGE
Organic remains of the Matinal strata, 818
Matinal (Trenton) limestone, 818
Organic remains of the Matinal shale, 820
Organic remains of the Levant strata, 821
Organic remains of the Surgent strata, 822
Organic remains of the Scalent strata, 824
Organic remains of the Pre-meridian strata, 824
Organic remains of the Meridian strata, 825
Organic remains of the Post-meridian strata, 826
Organic remains of the Cadent strata, 826
Organic remains of the Vergent series, 829
Organic remains of the Ponent rocks, 830
Organic remains of the Vespertine and Umbral strata, 830
Animal remains of the coal strata of Pennsylvania, 833
Notes on the Beyrichiæ and Leperditiæ of Pennsylvania, by T. Rupert Jones, 834
Fossil plants of the coal strata of Pennsylvania, 835
General remarks on the distribution of the coal-plants in Pennsylvania, and on the formation of the Coal, 837
Description of the fossil plants found in the anthracitic and bituminous Coal-measures of Pennsylvania, 847
First class.—Fungineæ, 847
Second class.—Algæ, 848
Third class.—Muscites, 849
Fourth class.—Calamariæ, 849
1.—Calamites, 849
2.—Equisetites, 850
3.—Asterophyllites, 851
4.—Annularia, 852
5.—Sphenophyllum, 852
Fifth class.—Filices (Ferns), 853
1. Neuropteridæ, 854
I. Noeggerathia, 854
II. Cyclopteris, 855
III. Neuropteris, 856
IV. Odontopteris, 860
V. Dyctiopteris, 861
II. Sphenopterideæ, 861
I. Sphenopteris, 861
II. Hymenophyllites, 863
III. Pachyphyllum, 863
III. Pecopterideæ, 864
Asplenites, 864
Alethopteris, 864
III. Callipteris, 865
IV. Pecopteris, 866
Ferns of undetermined affinity, 868
Stems, 868
1. Caulopteris, 869
2. Psaronius, 869
3. Diplostegium, 869
4. Stigmaria, 869
5. Sigillaria, 871
6. Syrigodendron, 873
7. Lepidodendron, 873
8. Ulodendron, 875
Fruits, 875
1. Lepidophyllum, 875
2. Lepidostrobus, 876
3. Brachyphyllum, 876
4. Cardiocarpon, 876
5. Trigonocarpum, 877
6. Rhabdocarpos, 877
7. Carpolithes, 877
8. Cordaites, 877

Catalogue of the Fossil Plants which have been Named or Described from the Coal-measures of North America.

Filices or fern leaves, 878
Neuropterideæ, 878
Sphenopterideæ, 879
Pecopterideæ, 879
Leaves of doubtful affinity, 880
Asterophylliteæ, 880
Stems of trees, 881
Cones or catkins and their scales, 883
Fruits or nutlets, 883

ON THE LAWS OF STRUCTURE OF THE MORE DISTURBED ZONES OF THE EARTH'S CRUST.

Wave-like form of all upraised tracts of the crust, 885
Exemplified in Pennsylvania and in the United States generally, 885
Parallelism of the crust-undulations, 886
Relations of flexures to each other, 887
Forms of the waves, 888
Symmetrical flexures, 888
Normal flexures, 888
Folded flexures, 889
Axis-planes, 890
Crust-waves, straight and curvilinear, 890
Flexures or waves of the strata, regarded longitudinally, 891
Of the distribution of flexures into groups, 892
Gradations in flexures, 892
Gradation from the folded to the symmetrical waves, 892
Gradations of structure in individual flexures exemplified, 892
Progressive expansion of the waves in one direction, 893
Exceptions to the prevailing law of steeper north-west than south-east dips in the Appalachian chain, 894
Progressive flattening-down of the flexures, 895
Fractures or faults in tracts of undulated strata, 895
General parallelism of the faults to the axis-planes, 897
Dislocation at an anticlinal axis-plane—uninverted side of wave shoved over the inverted, 897
Dislocation at a synclinal axis-plane, 898
Instances of great longitudinal dislocations, 898
Exemplification of the laws of flexure by the phenomena of some of the undulated zones of Europe, 899
Analogous phenomena of axes in Great Britain and Ireland, 899
Belgium and the Rhenish Provinces, 900
The Jura Chain of Switzerland, 901
The Alps, 901
The fan-like structure of the Alps, 901
General phenomena of slaty cleavage in the Appalachians, and other zones of plicated strata, 902
Cleavage approximately parallel with the strike, but independent of the dip of the strata, 902
Fan-like arrangement of the cleavage at the anticlinal and synclinal axis-planes, 903
Relation of cleavage to the mechanical constitution of the strata, 903

PAGE
The cleavage susceptibility alternately greater and less in parallel planes, ... 904
Foliation, ... 904
Examination of the prevailing theories of elevation, 905
Hypothesis of wedge-like intrusion of melted matter, 905
Intrusion of the igneous rocks in solid wedges, . 906
The upward movement of an igneous dyke would tend to stretch and not to corrugate the flexible strata, 906
Theory of upward tension against lines or points of the crust, ... 906
Hypothesis of corrugation from sinking of tracts of the earth's surface, ... 907
Hypothesis of a simple horizontal compression, . 907
Views of geologists concerning cleavage and foliation, 907
Examination of the prevailing theories of cleavage and foliation, ... 909
Theoretical views, ... 911
Theory of the flexure and elevation of undulated strata, 911
Theory of cleavage structure, ... 911
General Resumé, ... 912

CLASSIFICATION OF THE SEVERAL TYPES OF OROGRAPHIC STRUCTURE VISIBLE IN THE APPALACHIANS AND OTHER UNDULATED MOUNTAIN-CHAINS.

Features of General Erosion, ... 917
1. Erosion of horizontal strata, ... 917
a. Where each principal stratum is homogeneous as respects it hardness or softness, . . . 917
b. Where each separate stratum is complex in composition and degree of hardness, ... 918
2. Features of erosion of monoclinal belts, . . . 919
a. Where the strata are alternately firmly and feebly cohering, and those of each class are alike hard and soft, ... 919
b. Where there are several groups of strata differing in their degrees of hardness, ... 920
3. Features of erosion in anticlinal belts, . . 921
a. Where the lowest strata exposed, or those of the anticlinal axis or summit of the wave, are the hardest, 921
b. Where the lowest strata exposed along the anticlinal axis are softer than those resting on them, 922
4. Features of erosion in synclinal belts, . . 924
a. Where the highest strata exposed, or those of the synclinal axis or trough of the wave, are the hardest —of this class there are several varieties, . 924
b. Where the highest strata embraced in the synclinal flexure are relatively soft—of this class likewise there are several varieties, ... 924
Features of Local Erosion, ... 927
5. Local erosion of horizontal strata, . . . 927
a. Where the strata have the same general degree of hardness, ... 927
b. Where the strata alternate in hardness, . 928
6. Local erosion of monoclinal strata, . . . 929
a. Transverse ravines, ... 929
b. Longitudinal ravines in monoclinal belts, . 932
7. Local, ... 933
a. Erosion of anticlinal ridges, ... 933
b. Gaps or notches in anticlinal ridges, . . 933
8. Features of local erosion of synclinal belts, . 636
a. Erosion of the ends of synclinal ridges, . . 936
b. Erosion of the ends of synclinal valleys, . 937
c. Local erosion of synclinal belts, connected with transverse gaps or notches, ... 938
PAGE
d. Lateral gaps and breaches in synclinal basins, . 939
e. Modifications of the phenomena of general and local erosion dependent on wide deviations from symmetry of structure in the anticlinals and synclinals, 940
9. Denudation of unsymmetrical anticlinal belts, . 940
a. Erosion of unsymmetrical anticlinal ridges, . 940
b. Erosion of unsymmetrical anticlinal valleys, . 941

COAL-FIELDS OF THE UNITED STATES AND BRITISH PROVINCES.

CHAPTER I.

Description of the Coal-fields of the Provinces of British America, ... 942
Coal-field of New Brunswick, ... 945
Carboniferous district of Colchester and Hants, . 947
Carboniferous district of Pictou, . . . 948
Carboniferous district of Sydney County, . . 950
Carboniferous district of Guysborough, . . 950
Carboniferous district of Richmond and South Inverness, 951
Carboniferous district of Northern Inverness and Victoria, ... 952
Carboniferous district of Cape Breton County, . 952

CHAPTER II.

General description of the great Appalachian Coal-field, 954
Limits and dimensions, ... 954
Composition of the Coal-measures, . . . 956
Coal-beds, ... 957

CHAPTER III.

Illinois and Indiana Coal-field, ... 959
General description, ... 959
Western Kentucky Coal-field, ... 961
La Salle Coal-field, ... 964

CHAPTER IV.

Iowa and Missouri Coal-field—general description, . 964
Subdivisions of the Coal-measures, . . . 966
Composition of the Coal-measures, . . . 966
Organic remains, ... 967
Iron ores, ... 967

CHAPTER V.

Michigan Coal-field, ... 967

CHEMICAL CONSTITUTION AND PHYSICAL CHARACTERS OF THE BEST-KNOWN COALS OF NORTH AMERICA.

British Provinces, ... 969
United States, ... 969
Pennsylvania, ... 969
Virginia, ... 971
Kentucky, ... 973
Indiana, ... 974
Southern Illinois, ... 974
Middle Illinois, ... 975
Northern Illinois, ... 976
Missouri, ... 976

BRITISH COAL-FIELDS.

The Great South Wales Coal-field, ... 977
North Wales Basin, ... 978
Forest of Dean, ... 978
Coalbrookdale, ... 978

L318975

PAGE
South Staffordshire Coal-field, ... 978
North Staffordshire Coal-field, ... 979
Bristol Coal-field, ... 979
The Yorkshire and Great Central Coal-field, . . 979
The Ashby-de-la-Zouch Coal-field, . . . 980
The Derbyshire Coal-field, ... 980
The Nottingham Coals, ... 980
The Lancashire and Yorkshire Coal-field, . . 980
Coal-field of Durham and Newcastle, . . . 980
Cumberland Coal-field, ... 981
Scotch Coal-fields, ... 982
  The Mid-Lothian Coal-field, ... 983
  Lanarkshire Coal-field, ... 983
  Renfrewshire Coal-field, ... 984
  Ayrshire Coal-field, ... 984
  Fifeshire Coal-field, ... 985
  Dunfermline Coal-field, ... 985
  Clackmannan Coal-field, ... 985
Irish Coal-fields, ... 985
  Ballycastle Coal-field, ... 986
General Summary, ... 987
  Table of Coal Produce of Great Britain and Ireland, 1854 and 1855, ... 987

COAL—ITS COMPOSITION, AND A CLASSIFICATION AND DESCRIPTION OF ITS VARIETIES.

The Anthracite Coals, ... 991
The True or Dry Anthracite, ... 991
Semi-Anthracite, or Soft Gaseous Anthracite, . 993
The Bituminous Coals, ... 994
Hydrogenous Coal, ... 995
Causes of the gradations in Coal, ... 995
Conditions in the composition and structure of Coal affecting its economic value, ... 997
Table showing the relative properties and economic rank of the different classes of coal, . . 1000

METHODS OF SEARCHING FOR, OPENING, AND MINING COAL, PURSUED IN PENNSYLVANIA.

Searching for Coal, ... 1007
Surface-shafting, ... 1008
Boring, ... 1009
Opening or Proving Coal-seams preliminary to mining, 1009
Methods of mining Coal, ... 1010
  Open Cut, ... 1010
  By Drift, ... 1010
  By Tunnels, ... 1011
  By Slope, ... 1012
Introduction of Coal as a domestic fuel, . . 1012

AMERICAN AND EUROPEAN COAL-FIELDS.

Actual and relative areas—thickness and amount of coal in them—and present annual product of their mines, ... 1015
  Areas of Coal-fields, ... 1015
Comparative quantities of fuel in coal-lands and forest-lands, ... 1017
Dynamic value of coal, ... 1017
Amount of coal mined, ... 1018
Coal-trade of Pennsylvania, ... 1018
Anthracite Coal-trade of the United States, . . 1019

STATISTICS OF THE IRON-TRADE.

Production and manufacture of iron in the United States, ... 1020
Nickel, and copper mine of the Gap, Lancaster County, 1022
Additional sections, ... 1023
GLOSSARY, ... 1025
INDEX, ... 1028

ILLUSTRATIONS

IN THE

SECOND VOLUME.

SKETCHES OF SCENERY, &c.

FRONTISPIECE—BALTIMORE COMPANY'S MINES, WILKESBARRE.

SADDLE COAL-BED, NESQUEHONING MINES, ... *to face page* 60

LEHIGH SUMMIT, EAST MINE, ... 65

EAST WORKINGS IN OLD LEHIGH SUMMIT MINE, ... 66

MOUNT PISGAH PLAIN, MAUCH CHUNK, ... 73

PICTORIAL SECTION, EAST SIDE OF THE LITTLE SCHUYLKILL, AND NORTH SIDE OF THE COAL BASIN, TAMAQUA, ... 78

NEWKIRK (NEWARK ON PLATE) TUNNEL COLLIERY, NEAR TAMAQUA, ... 98

SILVER CREEK COLLIERIES IN 1853, SHOWING THE COAL-BREAKERS AND MOUNDS OF SLATE, ... 120

POTTSVILLE IN 1840, FROM THE NORTH, SHOWING THE GAP IN SHARP MOUNTAIN, ... 144

ROARING BROOK FALLS, NEAR SCRANTON, ... 338

INTERIOR OF BALTIMORE COMPANY'S OLD MINE, WILKESBARRE, ... 382

NANTICOKE GAP, WYOMING VALLEY, ... 399

LAUREL HILL AND PLAIN OF WESTERN PENNSYLVANIA, ... 468

PITTSBURG IN 1840, FROM GRANT'S HILL, ... 630

MAP OF THE MINING DISTRICT OF CHESTER AND MONTGOMERY COUNTIES, ... 675

SPANISH HILL, NEAR ATHENS, TIOGA COUNTY, A REMNANT OF A HIGH TERRACE OF NORTHERN DRIFT, ... 774

QUARRIES IN AURORAL LIMESTONE ON THE SCHUYLKILL, ILLUSTRATING CLEAVAGE, ... 905

COAL BENCHES, LOCUST MOUNTAIN, OPPOSITE LEHIGH SUMMIT MINES, ... 1008

OVERTURNED OUTCROP NEAR NEWKIRK, PENNSYLVANIA, ... 1008

OLD DRIFT IN THE FOURTEEN-FEET SEAM, NESQUEHONING MINES, ... 1011

COLLIERY SLOPE AND BREAKER AT TUSCARORA, ILLUSTRATING THE MANNER OF LIFTING THE COAL, AND BREAKING AND SORTING IT FOR THE MARKET, ... 1012

MAP OF THE ANTHRACITE AND BITUMINOUS COAL-FIELDS OF PENNSYLVANIA, ... 1019

TWENTY PLATES OF "FOSSILS OF COAL-FORMATION" (AT END OF VOLUME).

GEOLOGICAL SECTIONS.

PLATE I.—SECTION ON THE LITTLE SCHUYLKILL RIVER, NEAR TAMAQUA.
SECTION ON CASCA WILLIAM CREEK FROM MINE HILL TO MIDDLEPORT.
SECTION ON SILVER CREEK, EAST SIDE.
SECTION ON MILL CREEK FROM BROAD MOUNTAIN TO THE SCHUYLKILL RIVER.

PLATE II.—SECTION ON EAST NORWEGIAN CREEK FROM MINE HILL SOUTHWARD.
SECTION OF GATE RIDGE, POTTSVILLE.
SECTION ON MIDDLE NORWEGIAN CREEK.
SECTION ALONG WEST NORWEGIAN CREEK.
SECTION ON WEST BRANCH AND WOLF CREEK.
SECTION ON WEST-WEST BRANCH FROM MINE HILL TO SILVERTOWN.

PLATE III.—SECTION ON SWATARA CREEK.
SECTION ON LITTLE MUDDY BRANCH, BETTINGER'S MINES.
SECTION OF THICK MOUNTAIN NORTH OF DONALDSON.
SECTION OF BIG LICK MOUNTAIN.
SECTION ON MUDDY BRANCH AT WEAVER'S.
SECTION OF RED MOUNTAIN, TREMONT.
SECTION OF SHARP MOUNTAIN AT SWATARA AND RAUSCH GAPS.
SECTION ON RAUSCH CREEK FROM LITTLE LICK MOUNTAIN TO SHARP MOUNTAIN.
SECTION AT BEAR GAP, WICONISCO BASIN.
SECTION OF KLINGER'S GAP, WICONISCO BASIN.

PLATE IV.—SECTION FROM LAUREL HILL SLOPE (HAZLETON) TO SPRING MOUNTAIN.
SECTION ALONG WILKESBARRE AND TAMAQUA TURNPIKE FROM BUCK MOUNTAIN TO SPRING MOUNTAIN.
SECTION ON CATAWISSA ROAD AND THROUGH MAHANOY GAP NEAR ASHLAND, MAHANOY BASIN.
SECTION EAST OF MOUNT CARMEL.
SECTION FROM SHAMOKIN MOUNTAIN TO LOCUST MOUNTAIN.
SECTION ON LANDS OF BIG MOUNTAIN COMPANY ACROSS HEAD-WATERS OF GERHART'S RUN, TO LOCUST MOUNTAIN.

PLATE V.—SECTION DOWN ROARING BROOK AND THROUGH SCRANTON TO THE TURNPIKE ROAD WEST OF THE DIAMOND MINES.
SECTION FROM M'FARLANE'S SHAFT SOUTH-EAST TO THE BACK ROAD.
SECTION EAST FROM WILKESBARRE BY CANAL *VIA* WILLIAMS' STORE TO GARDINER CREEK.
SECTION ON PITTSTON PLANK-ROAD FROM BENEDICT'S MINE TO SHAFT NO. 4.
SECTION FROM CANAL ALONG EASTON TURNPIKE TO PROSPECT ROCK.
SECTION ON ROAD FROM CANAL TOWARDS SOLOMON'S GAP.
SECTION OF SOLOMON'S GAP.

PLATE VI.—SECTION ACROSS THE BASIN AT THE LEHIGH SUMMIT MINES.
SECTION HALF A MILE WEST OF EYSTER OR ZERBE'S GAP, TREVORTON.
SECTION SHOWING LONGITUDINAL PROFILE OF LITTLE LICK MOUNTAIN.
SECTION WEST SIDE OF EYSTER GAP, TREVORTON.
SECTION FROM SUSQUEHANNA RIDGE TO WARRIOR PATH GAP.

PLATE VII.—SECTION ALONG THE PENNSYLVANIA CENTRAL RAILROAD FROM PITTSBURG TO THE ALLEGHANY MOUNTAIN.

PLATES I.-XX.—FOSSILS OF THE COAL-FORMATION.
PLATES XXI. AND XXII.—PLANTS OF THE VESPERTINE AND UMBRAL SERIES.

VIEWS AND SECTIONS

(*PRINTED IN THE TEXT*—CONTINUED FROM VOL. I.)

FIG. PAGE
137. Subdivisions of the Coal Series of Pennsylvania, . 16
138. Section of the Coal Strata at Rhume Run, looking east, 54
139. Section of Coal, No. 6, Rhume Run, ... 58
140. Ground-Plan of Old Mine in the No. 6 or Thirty-nine-feet Coal at Rhume Run, ... 58
141. Saddle of the Big Coal of Rhume Run at the Short Tunnel, ... 61
142. Subdivision of the great Coal-bed of Summit Mines, . 65
143. Coal C of Tamaqua, ... 78
144. Coal D of Tamaqua, ... 78
145. Coal E of Tamaqua, ... 79
146. Greenwood Tunnel, in Locust Mountain, . . 83
147. Anticlinal Axis B, near Newkirk, with overturned outcrop, ... 97
148. Section of Newkirk Tunnel, ... 98
149. Coal (B?) C, Newkirk Tunnel, ... 101
150. Coal F (thickened), Newkirk Tunnel, ... 101
151. Buckville Tunnel, ... 102
152. Coal E, Buckville, ... 103
153. Tuscarora, or Palmer Coal of Tuscarora, . . 103
154. Coal E, Palmer Tunnel, ... 103
155. Grier Coal, Tucker's Slope, ... 103
156. Palmer Coal, Tucker's Slope, ... 104
157. Section of Strata at east end of Mine Hill, N. of Patterson, looking east, ... 104
158. Whitfield Tunnels, ... 105
FIG. PAGE
159. Section of the Basin C, at Tucker's Slope, head of Tuscarora Creek, ... 106
160. Section of Palmer's Tunnel near Tuscarora S., . 106
161. Section of Red-Ash Coals east of Tuscarora, looking east, ... 107
162. Coals, east end of Church Hill at Tuscarora, . . 107
163. Beachem's Tunnel entering Sharp Mountain south-west of Tuscarora, looking east, ... 110
164. Milford Tunnel, ... 113
165. Section at Preston's (Neville's) Colliery off New Philadelphia, looking east, ... 118
166. Section at Cwmbola from anticlinal J, looking east, . 126
167. Section of Tunnel in Bare Ridge (Pott and White's), . 127
168. Section on Zachariah's Run, looking east, . . 129
169. Ravensdale Tunnel, ... 130
170. Mann and Williams' Tunnel, Mount Laffy, looking east, 141
171. Section of Salem Hollow, looking east, . . 151
172. End view of Gate Ridge (Lawton's Hill), Pottsville, looking east, ... 152
173. Morgan and Edward's Tunnel, Otto Tract, looking east, 157
174. Bast and Pearson's Slope, ... 171
175. Serril's Upper Tunnel, Wolf Creek, looking east, . 171
176. Section, with Pictorial Background, of the Southern Coal-field near Tremont, looking west, ... 180
177. Tunnel in the Thick Mountain N. of Donaldson, looking east, ... 181

FIG. PAGE
178. Strata in Big Lick Mountain, ... 182
179. Strata in Red Mountain, ... 184
180. Section of south side of Red Mountain at Hebbard's Tunnel, 2 miles east of Tremont, looking east, . . 185
181. Section at Black Spring Gap, Dauphin Basin, . . 194
182. Section at Rausch Gap, Dauphin Basin, . . 195
183. Section at Yellow Spring Gap, Dauphin Basin, . 196
184. Section at Big Flats, Dauphin Basin, . . . 198
185. Section at M‘Ginnis's Colliery, Coal Castle, looking east, 205
186. Dyer's Run, Sando's Colliery, about 1 mile west of M‘Ginnis's, ... 206
187. Heckscherville Tunnel, looking east, . . . 207
188. Mecke's Tunnel, Meckesburg, looking east, . . 208
189. Mill Creek Basin, Broad Mountain, . . . 226
190. West Branch Basin, Broad Mountain, . . . 226
191. Coal Strata at the Little Schuylkill, . . . 227
192. Coal Strata on Silver Creek, ... 228
193. Coal Strata on Mill Creek, ... 229
194. Coal Strata in the Gorge of Mill Creek, opposite Wolf Creek (for comparison), ... 229
195. Coal Strata on West Branch and Wolf Creek, . 230
196. Coal Strata in the Thick Mountain at Donaldson, . 232
197. Section of the Sharp Mountain, looking west, showing overtilted strata and crushed coal-seams, . . 234
198. Flexure in Red Mountain Coal-bed, Lorberry Creek, . 235
199. Section of a Swell in the Big Coal of Lorberry Creek, Pinegrove, ... 236
200. Successive Phases of a Dislocated Flexure, . . 237
201. Cross Fractures displacing a Coal-seam, . . 237
202. Dislocation causing a Double Outcrop at Peach Mountain Seam near Minersville, ... 237
203. Section of “a Trouble” in a Coal-seam, . . 238
204. Coal of Wharton Creek, east of Jeanesville, . . 248
205. Big Coal, Jeanesville, at “Open Cut,” . . 250
206. Big Coal, Beaver Meadows, ... 250
207. East End of Spring Mountain, ... 251
208. Spring Mountain at Confluence of Beaver and Dreck Creeks, ... 251
209. Buck Mountain Basins, East Pismire Hill, . . 252
210. Section one mile east of Hazleton, . . . 252
211. Hazleton Basin, east of the Board Yard, . . 254
212. Coal Strata, Hazleton, ... 256
213. Big Coal of Hazleton—General Type, . . . 257
214. Big Coal, Hazleton, ... 258
215. Black Creek Basin, east of the Wilkesbarre Turnpike, . 261
216. East end of Little Black Creek Basin, Buck Mountain, 262
217. Buck Mountain, or Little Black Creek, east of the Wilkesbarre Turnpike, ... 262
218. Little and Big and Black Creek Basins, near the junction of the two branches of Black Creek, . . . 262
219. Buck Mountain, west of Black Creek Gap, . . 263
220. West end of Buck Mountain, ... 263
221. Section of East Green Mountain Basin, . . 264
222. Coal-bed of M‘Cauley's Mountain, . . . 264
223. One of the Cave Workings in the South Mine of the Great Lehigh Summit Coal-seam, . . . 264
224. General Section from Little Mountain to Broad Mountain, across the Shamokin and Mahanoy Basins, east of Big Mine Run, ... 266
225. East end of Head Mountain, looking west, . . 266
226. Head Mountain, south-west side of Lindner's Gap, . 268
227. Mahanoy Basin at eastern Origin of Bear Ridge axis, . 268
228. Broken Anticlinal Crest of Bear Ridge, half a mile east of the Ridge, ... 268
229. Section west of Mouth of North Mahanoy, looking west, 269
230. Section of east End of the Mahanoy Coal-field, . 269
231. Section at the Bear Ridge Tunnel, . . . 269
232. Western Origin of Bear Ridge Axis, . . . 270
233. Bear Ridge Tunnel, Mahanoy Basin, looking east, . 270
234. Mammoth Coal, Big Mine Run, ... 276
FIG. PAGE
235. Patterson's Coal, Little Mine Run, . . . 277
236. Section at Green Ridge Gap, ... 280
237. Connor's Mammoth Coal, Locust Run, . . . 285
238. Eckel's Coal VIII., near Mount Carmel, . . 286
239. No. 1 Mine, Lancaster Colliery, . . . 287
240. No. 2 Mine, Lancaster Colliery, . . . 287
241. Section of Green Ridge and Red Ridge at North Branch of Shamokin Creek at the Collieries looking east, . 289
242. Luke Fidler Coal-seam, ... 296
243. Section of Shamokin Mountain at Shamokin Gap, looking east, ... 299
244. Coals VIII. and IX. on Sunbury Railroad east of Shamokin, ... 300
245. Lowest Coal, Zerbe's Gap, ... 311
246. Coal I, Zerbe's Gap, Trevorton, ... 311
247. Coal II., west side of Zerbe's Gap, . . . 312
248. Coal III., near Zerbe's Gap, Trevorton, . . 312
249. Coal V., Zerbe's Gap, Trevorton, . . . 313
250. View of the Top Slate of Coal No. X., near Zerbe's Gap, Trevorton, showing matted flattened stems of Sigillaria, ... 317
251. Cobb's Gap, of Roaring Brook, ... 319
252. Vespertine and Umbral Strata at Solomon's Gap, . 320
253. Umbral Red Shale, Nanticoke Mountain, at Nanticoke, 320
254. Vespertine and Umbral Strata, Hertzoff Hollow, north of Kingston, ... 321
255. Wilkesbarre Lower Coal-measures near Solomon's, . 322
256. Wilkesbarre Upper Coal-measures (mouth of Mill Creek), 322
257. Campbell's Ledge above Pittston, Susquehanna Gap, . 326
258. Coal-measures at Carbondale, ... 331
259. Great Bed, Carbondale, ... 332
260. Archbald, ... 334
261. Hull's Coal, 6 miles north-east of Scranton, . . 337
262. General Section of the Coal-measures at Scranton, . 339
263. Coal F (Big Bed), New York and Pennsylvania Company's Slope Mine, ... 340
264. Coal B, Roaring Brook, ... 347
265. Coal D, Scranton, near the Rolling Mills, . . 347
266. Section of Griffin Ravine west of Scranton, looking north-east, ... 348
267. Coals F (Big) and E, River Bluff, near the Bellevue Mines, ... 349
268. Big Coal F, Pinebrook Mines, ... 351
269. General Section, Diamond Mines, ... 352
270. Shaft No. 2, Diamond Mines, ... 353
271. Coal H, Washburn Mine, ... 354
272. Coals H and G, Shaft No. 2, Diamond Mines, . 354
273. Coal G, near the Fellows' Mine, ... 354
274. Coal F, Shaft No. 2, Diamond Mines, . . . 354
275. Umbral Strata, showing position of Iron Ore, Stafford Meadow Brook, ... 358
276. General Section, Pittston and Port-Griffith, . . 361
277. Hollenback's Coal at opening near Canal, . . 369
278. Section at the Canal below the mouth of Mill Creek near Wilkesbarre, at the anticlinal flexure No. XVI., . 370
279. Section, Port Griffith Slopes and Borings, from Pennsylvania Company's draught, ... 373
280. Maxwell's Coal, ... 374
281. Wilcox Coal, Miner's Mill, ... 374
282. Lee's Coal, west side of Nanticoke Gap, . . . 378
283. Baltimore Bed at Old Mine, south-east of Wilkesbarre, 381
284. Section of Anticlinal Flexure No. XIX., near the foot of the lower inclined plane, Solomon's Gap, looking west, ... 389
285. Stiver's Bed, ... 390
286. Lane's Tunnel, east of Solomon's Gap, . . 393
287. Baltimore Bed (Blackman's), east of Breaker, . 393
288. Lower Big Coal at Landmesser's, east of Solomon's Gap, 395
289. Grey and Landmesser's Tunnel, near Solomon's Gap, 395
290. Carey's Run, 1½ mile west of Solomon's Gap, . 396

FIG. PAGE
291. Section in Gulick's Gap, Bergman's Run, 397
292. Section from Lee's, southward, at Nanticoke, 399
293. Section across the Wyoming Coal-basin, 5 miles west of Nanticoke, or through Schleppy's, 400
294. Hog-Back, 5 miles west of Nanticoke, 401
295. Colt's Coal, 403
296. Contortions in Little Mountain, east of Susquehanna River, 403
297 (*a*), 297 (*b*), 404
298. Section across the Coal-basin at its Western End, 404
299. Column of Coal-measures visible in Shoemaker's Ravine, north of Kingston, 406
300, 406
301. Coals in Shoemaker's Ravine, 406
302, 406
303, 407
304. Reynold's Small Bed on Smith's Creek, 408
305. Great Plymouth Bed, Harvey's Mine, 410
306. Plymouth Big Bed, Lance's Grand Tunnel, 410
307. Levy and Patton's, 410
308. Gaylord's Coal, Cooper Bed, 411
309. Reynold's (Smith's) Great Bed, one mile north of Reynold's Tunnel, 412
310. Section on Smith's Creek, west of Plymouth, 412
311. Section from Conglomerate by Gaylord's Mine, north of Plymouth, 412
312. Ground Plan of the Otto White and Grey Ash Collieries, 434
313. Diagram of Spangler and Eckel's Gangways, 439
314. Topographical Sketch, Shirley's Knob, Broad-Top Mountain, 449
315. Schell's Coal, 452
316. Orbison's (Barnett) Coal, 453
317. Philip Barnett's, 453
318. Broad-Top Improvement Company's Coal, 453
319, 320. Cook's Coal, 454
321. Lear Bed, 458
322. Strata in Round Knob, 459
323. Coal near "Mountain House," 460
324. Sandy Run, 461
325. Hopewell Company's Coal, 462
326. Lick Run, 470
327. Red Run, Ralston, 470
328. South-east side of Laurel Hill, Conemaugh Gap, 471
329. North-west side of Laurel Hill, Conemaugh Furnace, 471
330. Section of Strata exposed on Pennsylvania Railroad, in western half of Chestnut Ridge Gap, 472
331. A general vertical section of the Bituminous Coal Strata of Pennsylvania, west of the Alleghany and Monongahela rivers, compiled from numerous local sections, embracing the belt of country from Mercer to Green counties, 475
332, 504
333. Loyalsock, 509
334, 510
335. Lycoming Creek, 510
336, 510
337. Section of Mountains, on sides of Schroeder's Branch, or Carbon Creek, Second Basin, 512
338. Fall Creek, 512
339. Towanda Creek, 513
340. Miller's, 513
341. Barclay's Drift, 513
342. Mason's Drift, 513
343. Section west of Gatiss's, Towanda Basin, 513
344. Ralston Old Mines, 514
345. Astonville, on Railroad, Ralston District, 515
346. Section of Hill at Cartersville, $1\frac{1}{2}$ mile above Ralston, 516
347. Sellard's Ore, on Schroeder's Branch of Towanda Creek, 2 miles south of Canton, 517
348. Otter's Run, 518
FIG. PAGE
349. Morris's Run Strata, near Blossburg, 519
350. Blossburg Strata, 520
351. Coal Run, 521
352. Bear Creek, 521
353. Blossburg Vespertine and Ponent, 522
354. East Creek, 522
355. Johnson's Creek, 522
356. Wilson's Creek, 523
357. Lick Run, Farrandsville, 528
358. Tangascootac Creek, 529
359. Beech Creek, 530
360. Snowshoe, 530
361. Moshaunon, Phillipsburg, 531
362. Coal Hill, 532
363. Goss's Coal, 532
364. Section along the Susquehanna West Branch at Rattlesnake Run, showing the Vespertine Cliffs, 533
365, 534
366. Karthaus, 535
367. Curwinsville, 536
368. Clearfield Creek, 537
369. Caledonia, 539
370. Bennet's Branch Section, 539
371. At Emporium, 3d Basin, 541
372. Brandy Camp (opposite Horton's), 543
373. Little Toby Creek (Kyler's Coals), 543
374. Brandy Camp (Horton's), 543
375. Limestone Run, 543
376. Hemlock Run, 544
377. Reynoldsville, South Branch of Sandy Lick Creek, 544
378. Luthersburg, 545
379. Cliff Hill, 3 miles south of Wellsville, New York, 547
380. South of Smethport, 550
381. Potato Creek, 3 miles from Norwich, 550
382. Instantur, 551
383. Judge Wilcox's, 551
384. St Mary's (Fifth Basin), 552
385. Head-waters, South Branch Kenzua Creek, 554
386. Section exhibiting the two Sandstones overlying the Seral Conglomerate west of Smethport, with the Coal between, 554
387. Tunamaguont, 555
388. West of Kenzua, 556
389. South-west of Kenzua, 556
390. Little Alleghany River and French Creek, 556
391. Near Franklin, 556
392. Hills south-east of Alleghany River, near Warren, 557
393. Sugar Creek Lake, 559
394. Georgetown, and 10 miles north-east, 559
395. Two miles east and three miles south-west of Sharon, 560
396. Six miles north-west of Mercer, 560
397. Curtis's Coal, Sharon, 561
398. Four miles south-west of Franklin, 562
399. Three miles west of Sandy Creek Furnace, 562
400. A. Henderson's, Law's, &c., 562
401. Sandy Lake, 562
402. Three miles east of Mercer, 562
403. Mercertown, 565
404. Jenkin's Mill, 565
405. Mr Porter's, 565
406. Neshannock Creek, 565
407. Two miles west of Mercer, 565
408. Two miles above Newcastle, 566
409. One mile north-west of Newcastle, 566
410. Two miles below Newcastle, 566
411. Racoon Creek, Clarion River, 569
412. Lucinda Furnace, 569
413. Strattonville (three sections), 569
414. Deal's Bank, Shippensville, 571

FIG. PAGE
415. Deer Creek, 571
416. Scull's Run, 571
417. Rocklandtown, 571
418. Alsboch's, 571
419. Scrubgrass Creek, 573
420. Mercer, Sandy Lake, 573
421. Sandy Lake, 573
422. Lawrenceburg, 574
423. Slippery Rock Creek, 574
424. Beaver River, Newcastle Turnpike, 574
425. Neshannon Little Branch, 574
426. Lower Coal-measures, north-west Corner of Lawrence County, 575
427. Great Western Furnace, Sugar Creek, 577
428. Alleghany River, 7 miles above Sugar Creek, 578
429. Zelienople and Harmony, 579
430. Beaver River, 581
431. Old Brighton, 581
432. Below New Brighton, 581
433. On Ohio River, 581
434. Ohio River, Six-mile Run, 581
435. Armstrong's Mill, Clarion River, 584
436. One mile below Troy, 584
437. Brown's Cannel Coal, 585
438. Red Bank, 6 miles below Troy, 585
439. New Bethlehem, 585
440. Reynolds' and Schunk's Furnace, 585
441. Mouth of Mahoning, 585
442. Two miles above mouth of Mahoning Creek, 586
443. One mile west and two miles south-west of Punxutawney, 586
444. Mean's, Mahoning, 587
445. Freeport Limestone, 5 miles below Punxutawney, 587
446. Frampton's, 587
447. Dill's and Ewing's Mill, Mahoning Creek, 587
448. Smicksburg, 588
449, 588
450. Smith's Sawmill, 588
451. Two-Lick Creek, 590
452. Section compiled along Crooked and Plum Creek, 591
453. Crooked-Creek Bend, 591
454. Kittanning, 593
455. Alleghany Furnace, 594
456. Shady Run, 595
457. Freeport, 595
458. Leechburg, 597
459, 597
460. Below Warren, 597
461. Warren, 597
462. Three miles above Warren, 598
463. Four and a half miles above Warren, 598
464. Three and a half miles below Saltzburg, on the Kiskiminetas, 599
465, 600
466. Opposite Blairsville, 600
467. Saltzburg, 601
468. Loyalhanna, 601
469, 605
470. Jacob's Creek, 607
471. Map of Mount's Creek, 609
472. Youghiogheny Section, 610
473, 610
474. Youghiogheny Section, lower part of Connellsville, 611
475, 613
476. Section from Chestnut Ridge to the Pittsburg Coal-seam, 614
477, 478, 614
479, 615
480, 481, 482, 616
483. Pittsburg Coal-seam, 617
484. Pittsburg Coal-seam, 617
485. Loyalhanna River, 617
486. Conemaugh, 617
487, 488, 617
489. Pittsburg Coal, Nichol's Bank, 618
490, 618
491. Sewickly Creek, 618
492. Lemon's Coal, 619
493. Moyer's Coal, 619
494, 619
495. Byer's Coal, 619
496. Between Sewickly and Jacob's creeks, 620
497. Mount's Creek, 620
498. Connellsville, 621
499. Youghiogheny River, 621
500. Youghiogheny River, 621
501. Mount Braddock, 622
502. South of Mount Braddock, 623
503. National Turnpike, 623
504. Uniontown, Redstone Creek, 624
505. Redstone, 625
506. Oliphant's Furnace, 625
507. Virginia Line, 626
508. Cheat River, 626
509. Cheat River, Laurel Hill Gap, 626
510. Cat Run, 627
511. Newcomer's, 627
512. Smithfield, 627
513. Pittsburg Coal, 629
514. Loyalhanna, New Alexandria, 630
515. Type of Strata at Pittsburg, 631
516. Sewickly (Markle's Paper Mill), 636
517, 518, 636
519. Turtle Creek, 636
520, 521, 638
522. Sewickly Creek, 638
523. West of Robbstown, 638
524, 638
525. Big Sewickly Creek, 640
526. Youghiogheny River, 641
527. Williamsport, 641
528, 641
529, 642
530. Pike Run, 642
531. Below Greenfield, 642
532. Below Greenfield, 642
533. Brownsville, 642
534. Kreb's Knob, at Brownsville, 643
535. East of Brownsville, 643
536. Cox's Drift, 644
537. Mitchell's Drift, 644
538. Redstone Creek, 644
539. Brown's Run, 645
540. One mile above Brownsville, 646
541. Two miles and a half west of Carmichael, 646
542. Muddy Creek, 647
543. Whiteley Creek, 647
544. Mingo Creek, 648
545, 546, 547, 548, 650
549. Elk Lick Creek, 651
550. Elk Lick Creek, Salt Well, 651
551. Berlin, 651
552. Alleghany Summit, Pennsylvania Railroad, 652
553. Johnstown, 653
554. Stony Creek, 654
555. Below Red Bridge, on Stony Creek, 655
556. Paint Creek, 655
557. Rhoad's Camp, 655
558. Stoystown, 656
559. Milford and Ben's Creek, 657
560. Laurel Hill Creek, 657
561. Castleman's River, 658

FIG. PAGE
562. Castleman's River and Conglomerate Cliffs (in partial section), 658
563. Palæozoic Denudation, exhibited on Castleman's River, 659
564. Lockport, 661
565. Ligonier, 662
566. Indian Creek, 664
567. Contact of Mesozoic and older Palæozoic Rocks at Monroe, 681
568. A Chasm in the Auroral Limestone, south foot of Neversink Mountain, Reading, filled with Upper Mesozoic Conglomerate, 682
569, 691
570, 693
571. Leighton's Iron Mine, Warwick, Chester County, 708
572. Ore-ground at St Mary's, Old Warwick Pits, Chester County, 708
573, 718
574. Section across Kittatinny Valley, from Blue Mountain to Cornwall, 15 miles, 718
575. Map of the Cornwall Ore Hills, Lebanon County, 719
576. Section through Cornwall Iron Mines, Lebanon County, along line *a b*, 719
577. Big Mine Ore Hill, Cornwall Iron Mines, Lebanon County, 719
578. Ore Quarry, east base of Big Hill, Cornwall, Lebanon County, 720
579. Guth Mine, 723
580. Kern and Albright's and Hoffman's Mines, near Siegerville, 723
581, 724
582. Ore Pits, 726
583. Surgent Fossiliferous Ore Group, Hollidaysburg, Blair County, 730
584. Synoptic Diagram of the European Formations, 742
585. 1. Conformable Continuous Sequence; 2. Conformable Interrupted Sequence; 3. Unconformable Continuous Sequence; 4. Unconformable Interrupted Sequence, 777
586. Hasbruck's Quarry, Rondout, showing unconformity of Pre-meridian upon Matinal strata, 785
587. Oblique Deposition by Strewing, 812
588. Oblique Stratification from Suspension, 813
589. Scolithus linearis, 816
590. Paradoxides spinosus, from a quarry in Quincy, Massachusetts, one-third its natural size, 816
591. Leptæna incrassata, 817
592. Atrypa plicifera, 817
593. Murchisonia bicincta, 817
594. Raphistoma staminea, 817
595. Maclurea magna, 817
596. Orthoceras multicameratum, 817
597. Chætetes lycoperdon, 818
598. Strictopora acuta, 818
599. Leptæna sericea, 818
600. Leptæna alternata, 818
601. Orthis testudinaria, 818
602. Orthis pectenella. (N. S.?) 818
603. Orbicula. (N. S.?) 818
604. Lingula curta, 818
605. Ambonychia bellastriata, 819
606. Pleurotomaria subconica, 819
607. Bellerophon bilobatus, 819
608. Orthoceras vertebrale, 819
609. Conularia Trentonensis, 819
610. Isotelus gigas, 819
611. Trinucleus concentricus, 820
612. Graptolithus pristis, 820
613. Calymene Beckii, 820
614. Agnostos lobatus (1 and 3 natural size, 2 and 4 enlarged), 820
615. Lingula quadrata, 820
616. Delthyris lynx, 820
617. Avicula insueta, 820
618. Modiolopsus modiolaris, 820
619. Cyrtolites ornatus, 820
620. Pleurotomaria bilix, 820
621. Ormoceras crebriseptum, 821
622. Glyptocrinus decadactylus, 821
623. Arthrophycus Harlani, 821
624. Bucauia trilobatus, 822
625. Buthotrephis gracilis (?), 822
626. Rusophycus bilobatus, 822
627. Coruulites, 823
628. Avicula subplana, 823
629. Lingula oblonga, 823
630. Leptæna depressa, 823
631. Leptæna patenta, 823
632. Atrypa cougesta, 823
633. Atrypa reticularis, 823
634. Atrypa intermedia, 823
635. Orthus elegantula, 823
636. Orthoceras imbricatum, 823
637. Calymene Clintoni, 823
638. Teutaculites ornatus, 824
639. Onchus (?) Deweii, 824
640. Atrypa peculiaris, 825
641. Atrypa, 825
642. Atrypa lævis, 825
643. Delthyris macropleura, 825
644. Spirifer sulcatis, 825
645. Rhynconella nobilis, 825
646. Pentamerus galeatus, 825
647. Platyostoma, 825
648. Strophomena punctulifera, 825
649. Meganteris oviodes, 826
650. Spirifer Arenosa, 826
651. Atrypa unguiformis, 826
652. Atrypa limitaris, 826
653. Orbicula minuta, 826
654. Orthoceras subulatum, 826
655. Cyathophyllum turbinatum, 827
656. Fenestella? 827
657. Avicula decussata, 827
658. Modiola concentrica, 827
659. Avicula flabella, 827
660. Microdon bellastriata, 827
661. Orthonota undula, 827
662. Avicula, 827
663. Avicula, 827
664. Posidonia or Estheria, 827
665. Strophomena crenistria, 827
666. Strophomena demissa, 827
667. Spirifera spiriferoides, 828
668. Spirifer mucronata, 828
669. Delthyris medialis, 828
670. Delthyris congesta, 828
671. Atrypa aspera, 828
672. Tropidoleptus carinatus, 828
673. Delthyris granulifera, 828
674. Productus hirsutus, 828
675. Lepidodendron primævis, 828
676. Goniatites interruptus? 829
677. Lepidodendron, 829
678. Avicula damnoniensis, 829
679. Avicula, 829
680. Strophomena Chemungensis, 829
681. Atrypa hystrix, 829
682. Atrypa eximia, 829
683. Delthyris cuspidata, 829
684. Ponent Fern? 830
685, 831
686. Trail of a Mollusc? 832
687. Productus, 833

FIG. PAGE
688. Pentremites, 833
689. Avicula, 833
690. Nucula ? 833
691. Pleurotomaria, 833
692. Nautilus decoratus, 833
693. Lingula, 833
694. Spirifer of the Coal Strata, 833
695. Beyrichia Maccoyiana, 834
696. Beyrichia Pennsylvanica (different stages of growth), 834
697. Leperditia ovata, 834
698. Leperditia Gibbera, Var. Scalaris, 834
699. Leperditia Pennsylvanica, 834
700. Kittatinny Mountain on the west side of the Delaware Water-Gap, 884
700*a*. Kittatinny Mountain on the east side of the Delaware Water-Gap, 884
701. Symmetrical Flexure, 888
702. Normal Flexure, 889
703. Folded Flexure, 890
704. Undulations in Scalent Variegated Shales and Sandstones on Pennsylvania Railroad, Juniata River, below Mifflintown, Juniata County, looking south-west, 894
705. Undulations in Scalent Variegated Shales on Juniata River, below Lewistown, looking south-west, 894
706. Generalised Section of the Appalachian Chain from north-west to south-east, through the Juniata District of Pennsylvania, 895
707. Delaware Water-Gap, 896
708. Upward Displacement of uninverted side of fractured anticlinal, 898
709. Upward Displacement of inverted side of fractured synclinal, 898
710. Upward Displacement of whole anticlinal flexure ; fault in the inverted side, 898
711. Downward Displacement of uninverted side of fractured anticlinal, 898
712. Downward Displacement of inverted side of fractured synclinal, 898
713. Downward Displacement of whole anticlinal flexure ; fault in the inverted side, 898
714. Generalised Section of the Alps, displaying the Dipping of the Folds of the Strata on both Sides in towards the Igneous Axis, 902
715. Fan-like arrangement of Cleavage at an Anticlinal Axis, 903
716. Beds of Red Shale with Cleavage alternating with beds of Sandstone without Cleavage ; Cleavage curving towards parallelism with the bedding at its boundaries. Section near Ashland, Pennsylvania, 903
717. Dykes expanding upwards in Anticlinals and downwards in Synclinals, 906
718. Cleavage in Red Shale, caused by a Trap-dyke parallel to its walls, near New Hope, Pennsylvania, 912
719. Cleavage superinduced by a Trap-dyke in Red Argillaceous Sandstone of Jurassic (?) age, west of Gettysburg, Pennsylvania, 912
720. Plateau with simple Escarpment, Shelf of Niagara, 918
721. Plateau with complex Escarpment, Mountain Ridge, New York, 918
722. Terraced Plains, 918
723. Plateau with Terraced Escarpment, Pokono Mountain, 918
724. Plateau with upper Escarpment terraced, Alleghany Mountain, Pennsylvania, 918
725. Plateau with lower escarped Slope terraced, Catskill Mountain, 919
726. Ridged and grooved Plain, 919
727. Ridged and grooved Table-land, 919
728. Single-crested Monoclinal Ridge, 920
729. Double-crested Monoclinal Ridge, 920
730. Double Monoclinal Ridge, with terrace on the back, 920

FIG. PAGE
731. Double Monoclinal Ridge, with terrace on the front, 920
732. Complex Monoclinal Ridge, 920
733. Complex Monoclinal Ridge, 920
734. Monoclinal Ridge, a Profile of the Kittatinny Mountain, near the Susquehanna (strata inverted), 920
735. Simple Monoclinal Valley, 921
736. Double Monoclinal Valley, 921
737. Complex Monoclinal Valley, 921
738. Single-crested Anticlinal Ridge, 921
739. Triple-crested Anticlinal Ridge, 921
740. Double-crested Anticlinal Ridge, or simple Valley of Elevation, 922
741. Complex Valley of Elevation, 922
742. Complex Valley of Elevation, with central Anticlinal Ridge, 923
743. Simple Synclinal Ridge, flexure close, 926
744. Simple Synclinal Ridge, flexure open, 926
745. Synclinal Ridge in Synclinal Valley, or Triple Synclinal Ridge, 926
746. Triple Synclinal Ridge or Terrace, 926
747. Simple Synclinal Valley or Basin, 926
748. Complex Synclinal Mountain, 927
749. Complex Synclinal Valley, 927
750. Mounds and Hollows in the Drift, 928
751. Benched Outcrop of Coal Strata, 929
752. Terraced Hill-sides, 929
753. Level Ravine in Monoclinal Ridge viewed from above, perpendicular to strike, 929
754. Level Ravine in Monoclinal Ridge, oblique to strike, 930
755. Sloping Ravine, descending in the direction of the dip more *rapidly* than the strata do, towards the observer, 930
756. Sloping Ravine, descending in the direction of the dip more *gently* than the Strata do, towards the observer, 930
757. Sloping Ravines cutting Terraces on the dipward side of a Ridge, 931
758. Sloping Ravine descending against the Dip, 931
759. Gap in a Simple Monoclinal Ridge, 932
760. Gaps intersecting Monoclinal Ridges, 932
761. Gap in an Anticlinal Ridge of hard strata, 933
762. Gap or Oval Pass in an Anticlinal Ridge, the lower stratum being soft, 933
763. Gap in an Anticlinal Ridge. Complex variety arising from two hard and two soft strata, 935
764. Gap in Anticlinal Ridge. Complex variety produced by three soft and two hard strata, 935
765. Profile of a Synclinal Knob, 938
766. Diluvial Scratches deflected up and along the South Mountain Barrier of the Wyoming Valley, 941
767. Section of Strata north-west side of Laurel Hill, Cheat River, Virginia, 957
768. Upper Coal-measures, Holloway's Borings, Henderson County, Kentucky. From D. D. Owen, 962
769. Lower Coal-measures of Kentucky. From D. D. Owen, 962
770. Overturned Outcrops of Coal-Seams, 1008
771. Mouth of Drift in Horizontal Strata, 1010
772. Montelius's Open Cut, Mill Creek, Mine Hill Valley, 1010
773. Part of Underground Workings of the Primrose Coal-seam at Neill's Colliery on Silver Creek, from Plan by G. K. Smith, Mining Engineer of Pottsville, 1011
774, 1023
775. Section through Penn's Valley and east end of Kishacoquillas Valley, showing Terraced Ridges, 1023
776. Section from Gap in Town Hill to Warrior Ridge, along the Rainsburg Road, 1024
777. Section from Tussey Mountain, near Alexandria, to Jack's Narrows of Juniata, 17 miles, 1024
778. Section from the neighbourhood of Tamaqua, across Locust Valley and the west ends of the Beaver Meadow and Bucks Mountain Basins, 1024

GEOLOGY OF PENNSYLVANIA.

BOOK VIII.

EIGHTH PALÆOZOIC DISTRICT, OR ANTHRACITE COAL-BASINS, & ENCIRCLING BELTS OF THE OLDER CARBONIFEROUS ROCKS.

INTRODUCTION.

POSITION OF THE ANTHRACITE BASINS IN THE MOUNTAIN-CHAIN; LIMITS AND SUB-DIVISIONS OF THE DISTRICT; STRATA, AND THEIR RELATIONS TO THE TOPOGRAPHY; CLASSIFICATION OF THE COAL-MEASURES.

Having in the several foregoing divisions of this work described all the Palæozoic strata within the State, from the base of the system to the top of the Ponent series, I shall proceed to set before the reader the geological structure and contents of the very important district which embraces the Anthracite Coal-fields. To acquire a full and clear conception of the nature, distribution, and positions of the strata, it is essential we should take a comprehensive preliminary survey of the region, see why it occupies the place it does, learn its boundaries and subdivisions, and trace its formations under their variations of composition and thickness.

GENERAL STRUCTURE OF THE MOUNTAIN-CHAIN IN ITS RELATIONS TO THE ANTHRACITE BASINS.

The whole region from the Southern part of the Atlantic Slope to the Northern border of the State may be viewed in a broad light, as composed of two great systems of crust-undulations : one group entering the State from the N.E., and expiring between the Schuylkill and the Susquehanna in the Southern half of the State, and between the waters of Pine Creek and those of the Western streams in the Northern; the other occupying the country W. of the main Susquehanna and its W. branch, and expiring North-eastward, within the same districts as the first—the two sets, indeed, interlocking at their extremities.

The waves of the first or North-eastern belt are for the most part comparatively broad and gentle flexures, and except in the local group of the South Mountains east of the Schuylkill, they do not lift relatively deep-seated formations to the surface. The other, or South-western set, on the contrary, elevate at intervals the lower Palæozoic rocks throughout the entire breadth of the middle zone of the chain, from the Cumberland Valley to the Bald Eagle Mountain, the corrugation of the crust being in much steeper waves in this quarter than in the other. In the district S. and S.E. of the Alleghany Mountain, the subsidence of the two systems of undulations here mentioned, towards each other, causes the whole tract of country lying between them to contain a greater depth of the stratified rocks than either of the more corrugated districts themselves possess. The general erosive action of the oceanic waters, disturbed by the billowy oscillations of the crust and the permanent uprising of these belts of anticlinal flexures, has planed down to a nearly common level all portions of the uplifted zone, so that that division or segment of the chain which received the least amount of upward movement—the district, namely, between the sinking ends of the two systems of anticlinal waves—was the most protected from denudation, and retains the largest proportion of the strata originally deposited on the highest formations. It is in virtue of these conditions, namely, a less vertical upheaval and a less depth of denudation, that the mountain-chain here contains between the two regions of more prominent anticlinal flexures a broad tract of parallel synclinal basins. Thus it is, that low on the Atlantic Slope there exists in this position the deep synclinal trough of the Montgomery and Chester Valley; that a little further to the N.W. there lies between the terminations of the North-eastern and South-western anticlinals, or those respectively of the South Mountains east of the Schuylkill, and the South Mountains west of the Susquehanna, the broad plain of limestone and red shale in Lancaster, and the counties adjoining; and that, thirdly, within the Appalachians proper there occur the deep troughs of anthracite coal, in which the highest of all the Palæozoic formations have escaped denudation. A little attention to the topographical and geological features of this middle or synclinal region, as presented on the Map, will make it apparent that all the chief anticlinal flexures of this quarter are simply the terminal portions of the great waves of the two anticlinal zones here meeting and passing each other. Only upon this comprehensive view can we understand the curious laws which regulate the distribution of the lesser or secondary undulations which corrugate every part of the coal-field, or comprehend satisfactorily the source and nature of the dislocations which traverse it in so many places, and with such seeming want of regularity.

Looking at the order of distribution of the chief or primary flexures which make up each of the two great systems between the Atlantic Slope and the Alleghany Mountain, we discover a very interesting feature of symmetry in each. Those of the North-eastern system, or the set of flexures entering the State from New Jersey and New York, and expiring towards the S.W., are beautifully arranged in echelon in greater and lesser groups, each group penetrating to a less distance Westward than that next S. of it; so that the whole belt from Lancaster County to the Eastern Middle Coal-fields ends nearly on one meridian, a line or narrow belt not rigidly straight trending a little E. of N. through Lancaster and Pottsville. The reader will discern at a glance this relation of the flexures of the strata, if, with the Map before him, he will cast his eye through the Western points of the Mine Hill, Welch Mountain, South Mountain at Reading, the spurs of the Blue Mountain between Port Clinton and Orwigsburg, those of the Sharp Mountain at Middleport, of the Nesquehoning and Broad mountains, and those of the table-land of the Middle

Coal-field west of the Lehigh. Nor does this retreating of the anticlinals, as we proceed Northward, cease at the Lehigh, for it is clearly discernible in the curious echelon arrangement of the saddles, entering the S.E. side of the Northern anthracite fields from the Eastward. There is, in keeping with this curious symmetry—into which, indeed, it enters as one element—an approximate equality of interval between the larger groups of undulations. From the Welch Mountain, or gneissic area E. of it, to the Wyoming coal-field inclusive, we may count five great belts of flexures—namely, those of the Welch Mountain, the South Mountain, the Blue Mountain, the Lehigh and the Lackawanna coal-fields. These are not strictly equidistant, but lie at slightly wider and wider intervals as we cross them Northward—a feature in strict harmony with the very general law of the crust-undulations of the Appalachian Chain, whether group is compared with group in an extensive zone, or individual flexure with flexure in a single belt.

Turning to the South-western system of undulations, or those which originate beyond the Susquehanna, and expire Eastward against or past the ends of the North-eastern system between the Susquehanna and the Schuylkill and Lehigh, we observe a symmetry in the relative arrangement of the chief waves or groups of waves which is even more remarkable. In this instance, as in the other, they are disposed in echelon, but the more North-western, in place of retreating, protrude past their neighbours on their S.E., outflanking them with a beautiful regularity. But in place of terminating on a Meridian, or line running N. and S., the more Northern flexures overpass the Southern ones so much, that a line connecting the extremities of the whole system—necessarily not a very straight one—will have rather a N.N.E. and S.S.W. direction, than a N. and S. one. It is to this circumstance that we are to impute the singularly oblique disposition of the anthracite coal-basins, or the overrunning of the Northern, Eastward of the more Southern, a distribution which, viewed in its economical bearings, is of immense importance, since it renders the Northern coal-fields almost as accessible to the tide-waters of the Hudson as the Southern ones are to those of the Delaware and Chesapeake. But for this interesting distribution in echelon, the Wyoming or Lackawanna coal-field would have lain to the N.W. and not to the N.E. of the Pottsville and Mahanoy basins, and its rich stores of fuel would have been hemmed in by a much wider belt of mountains than that which now separates them from the great coal-consuming markets of New York and the Eastern States.

As in the case of the North-eastern flexures, these of the South-western system observe a beautifully regular gradation of expansion as we measure the breadth of the waves in their order Northward, but this dilatation appears to be very gradual. Starting with the South Mountains of Cumberland and Adams counties as one belt, and viewing the closely-folded flexures in the Matinal shales between Harrisburg and the Blue Mountain as another, and then adding as a single wave each of the five anticlinal belts penetrating Eastward between the Western ends of the coal-basins—namely, those of Armstrong, Mahantango, Roaring Creek, Wapwallopen, and Harvey's Lake valleys, we find the entire zone to include seven great undulations, or, more truly, seven compound groups of anticlinal flexures. If to these we further add, what legitimately belongs to them, the great anticlinal wave whose crest or axis ranges along the N.W. margin of Nittany Valley, and through Nippenose Valley, and the spur of the Bald Eagle Mountain, we shall find the total number of primary flexures at the Susquehanna to be eight, excluding those N.W. of the Alleghany Mountain. If the reader, wishing to compare the relative distances of these great belts of elevation of the strata, will, with the Geological Map before him, measure their spaces with a pair of compasses anywhere between the primary geological sections Nos. VI. and VII.,—starting, say, at the Eastern end of the South Mountains,—he will notice a slight increase of interval until he reaches the last space, or that between the Brush Valley axis and the axis of Nittany Valley, where an extensive dislocation along the latter, with overturn of the N.W. leg of the wave, causes the interval to be abnormally reduced.

In the South-western portion of the Appalachian Chain which fills the interval between the Susquehanna and the Potomac rivers, the grouping of the flexures is essentially different from that which I have just outlined. Towards the S.E. or E. we have still the great anticlinal belt of the South Mountains, or the Blue Ridge, exposing numerous compressed waves of the Primal rocks. West of this, on the opposite side of the Appalachian Valley, is the next main compound anticlinal tract, comprehending Path Valley and M^cConnell's Cove, and lifting to the day the Auroral limestone. Beyond this there lies a broad deep basin of all the higher Palæozoic rocks up to the Coal-measures inclusive, and W. of it, again, a third wide complex anticlinal belt again elevating to the day the Auroral rocks in Morrison's, Friends', and Milliken's coves. Thus between the Juniata River and the State of Maryland the flexures of the Appalachian Chain, roughly grouped, arrange themselves in three broad anticlinal tracts—those of the South Mountains, of Path Valley, and of Morrison's Cove respectively; and three equally wide and complex synclinal ones—those of the Cumberland Valley, of Broad-Top Mountain, and of the Cumberland coal-basin.

Having thus reviewed the general structural features of the mountain-chain, and shown how its great anthracite basins have come to be where they are, and why they are so far detached from the main coal-field of the country, while elsewhere along the chain, except in the Broad-Top Mountain, all the Coal-measures have been swept away, I shall proceed to give a summary sketch of the coal region itself, preliminary to a systematic and minute description of each of the several basins and its contents.

GENERAL LIMITS OF THE ANTHRACITE DISTRICT.

The zone of carboniferous rocks embracing the anthracite basins of Pennsylvania is a long irregular tract of a rudely-rhombic shape, stretching from the W. edge of Wayne County South-westward to the E. corner of Perry; bounded on the N. by the Northern base of the Wyoming and Shickshinny Mountain, on the S. by the Orwigsburg Valley, on the E. by the Moosic Mountain and upper waters of the Lehigh, and on the W. by the Susquehanna. It may be viewed as a rolling plateau somewhat elevated above the surrounding valleys, and containing many slender parallel mountain-ridges, some broad included table-lands, and numerous long narrow valleys. Its Western margin is very deeply indented by four large anticlinal coves of the Ponent and Vergent formations, subdividing this side of the tract into five synclinal belts of basins, each including an independent coal-field. Its Eastern border is more vaguely defined, the lower carboniferous rocks, or Vergent and Umbral strata, lifting themselves gradually to the N.E. beyond the Lehigh, and thinning off there by a very irregular denudation in the table-land of Monroe and Pike counties. Assigning as its precise geological boundary the outer edge or lowest stratum of the Vespertine sandstone, this carboniferous district may be somewhat accurately defined as follows: Its S. or S.E. border ranges along the outer crest of the Mahoning or Second Mountain from the Knob of the Kettle, E. of the Lehigh to the Knob of the Cove Mountain, W. of the Schuylkill. Thence along the N. brow of Peter's Mountain to Short Mountain at the head of Powell's Valley, and through the outer summit of Short Mountain, round the head of Armstrong Valley, to the S. brow of Berry's Mountain, and along the latter to the Knob of Buffalo Mountain, near the Juniata. Pursuing thence an E. course, it stretches along the N. brow and slope of Mahantango to its junction with Line Mountain, doubles abruptly to the W., and follows the latter to the Knob of Mahanoy Mountain at the Susquehanna, where, deflecting abruptly to the E. again, it takes the slope of Mahanoy Mountain, and its extension, Little Mountain, to the head of Roaring Creek Valley. Here the boundary turns W., winds along the W. brow of the Catawissa Mountain and its spurs to the N. slope of the Nescopeck Mountain, which it follows Eastward to the head of the Wapwallopen Valley. There, after two or three windings, the line takes the Southern slope of the Pond Mountain to its junction with the Shickshinny Mountain near Fishing Creek, where, bending sharply towards the E., it ranges along the latter high on its N. flank to the North Branch of the Susquehanna, beyond which, gradually deflecting more and more towards the N., and receding from the mountain, it approaches the N. point of the Lackawanna coal-basin. Curving with a wide sweep round the head of this coal-field, the boundary, always the limit between the Ponent and Vespertine strata, becomes irregular and difficult to define ; but we shall arbitrarily assume a line drawn from the headwaters of the North Branch of the Wallenpaupack to Beaver Lake of the Lehigh River for part of the E. limit of the tract, the remainder being the channel of the Lehigh River from Beaver Lake to the Kettle Mountain, near which we started.

The very tortuous margin here traced encloses an irregular parallelogram of mountains and valleys, measuring, in superficial area, about 1668 square miles, the length of which from N.E. to S.W. is about 100 miles; and its greatest transverse breadth, through Mauch Chunk and Nanticoke, is not less than 30 miles. The coal-formation proper constitutes but a small part of this large area of the carboniferous rocks. It will be shown hereafter to comprise less than 300 square miles.

Natural leading Subdivisions of the District.—The district of carboniferous strata of Eastern Pennsylvania, defined in the foregoing brief description, may be subdivided naturally into three tracts, a Southern, Middle, and Northern. The Southern is separated from the Middle on the W. by the anticlinal belt of Ponent and Vergent strata, occupying Mahantango Valley, and on the E. by the much more slender anticlinal valley of Little Bear Creek, between Kettle Mountain and the Pokono. The Middle is separated from the Northern by the long regular anticlinal valley watered by the Wapwallopen Creek and the Berwick Reach of the Susquehanna. Each of these three tracts is a complex synclinal basin, enclosed within a mountain-rim of Vespertine sandstone, except where they coalesce over the anticlinals which only partially insulate them ; each is undulated into numerous anticlinal and synclinal flexures, the axes of which traverse it longitudinally with a slight obliquity, and each contains, as its central uppermost formation, a large area of the anthracite Coal-measures. The S. tract encloses the Schuylkill or Pottsville coal-basin, including both its W. spurs and also the Broad Mountain ; the middle tract, the Shamokin and Mahanoy coal-basins with their branches, and the group of basins lying between the Lehigh and the Catawissa ; and the N. tract, the basin of the Lackawanna and Susquehanna, or the Wyoming coal-field; and each of these undulated troughs of the coal strata, rimmed round by a mountain-barrier of the coarse and hard lower coal rocks, is further encircled and shut in by a deep valley of the soft Umbral red shales, and by a second mountain-barrier outside of this, composed of the hard Vespertine sandstones and conglomerates. The only quarter where the Coal-measures are not thus engirt by a double rim of mountains is the N.E. half or Lackawanna division of the N. basin. There the Umbral formation being abnormally thin, the two hard projecting strata—the coal conglomerate and the Vespertine sandstone—lie unusually near to each other, and generally form but one broad mountain-ridge, with a bench or terrace of the intermediate Umbral shale.

It is an interesting and important feature in the structure of this carboniferous district, that all its subdivisions, as well its primary as its lesser, down to its most trivial ones, are determined by its anticlinal flexures and the denudation or cutting away of the strata over them; and the absence of any symmetry between the E. and the W. terminations and spurs of the coal-fields, results simply from the fact that these flexures do not consist of a single system of waves running through and through the region, but—as intimated in a former Chapter—of two sets overlapping each other, and expiring within it. A very little study of the Map will render this perfectly obvious, and will show, moreover, how many of the interior features of the coal-basins, even those of insignificant magnitude, are the consequences of flexures of primary importance in the regions exterior to this district. A detailed description of the flexures of the strata is reserved for the future Chapters treating of the special coal-basins in their minuter features, but it is expedient meanwhile to notice the effects of two of the chief anticlinals which enter the region from the E. and W. Only one great flexure from the E., or from beyond the Lehigh, seems to penetrate the district far towards the centre. This is the axis of the Nesquehoning Mountain or of Little Bear Creek. Originating in the Vergent rocks S. of the Pokono, and then gradually declining W., it is saddled by Ponent strata in the valley of Little Bear Creek as far as the Lehigh. Beyond this river the flexure is a broad flat wave, spanning the whole interval from the S. to the Beaver Meadow Basin, exposing in its centre the Vespertine rocks throughout the breadth of the Nesquehoning Mountain. Further W. the Umbral red shales occupy the back of this anticlinal in a wide valley at the sources of the Little Schuylkill, and continuing to subside, it expires under the coal conglomerate of the Broad Mountain. The main axis of this compound wave extends through the W. point of Nesquehoning Mountain, and through the Southern cove in Broad Mountain, at the source of Locust Creek, and the red-shale hollow in Broad Mountain E. of Mill Creek. Other lesser flexures, subordinate to the same broad wave, entering the region from the Pokono Mountain or beyond it, and ranging through the Nesquehoning Mountain, die out in the Broad Mountain north of the principal one. It is this group of anticlinals which insulates the E. end of the Southern from the E. portion of the middle coal-field by lifting the red shale to the surface, and further W. the conglomerate in the Broad Mountain.

Nearly opposite to the wide anticlinal belt just described, a still more prominent one penetrates the region from the W. This latter great wave, also a compound flexure, after elevating the middle Palæozoic formations in the Mahantango Valley, rapidly sinks towards the E., and enters the carboniferous rocks at the junction of the Line and Mahantango mountains. From this point E. to the head of the Little Mahanoy it is arched by the Umbral red shale, and throughout this distance insulates the Broad Mountain from the Mahanoy coal-basin. Subsiding in the conglomerate near the N. edge of the Broad Mountain, it separates the Coal-measures of that table-land from those of the middle coal-field Northward. It thus appears that the Nesquehoning and Mahantango anticlinals pass or overleap each other in the Broad Mountain; and it is to this circumstance, and to their being themselves compound undulations of the strata, that the Broad Mountain contains several subordinate flat saddles of the conglomerate and intermediate shallow basins of the Coal-measures.

The middle division of the district comprises, as we have seen, all that area which lies between the Nesquehoning Mountain and Mahantango Valley on the one side, and the valley of the Wapwallopen and N. branch of Susquehanna on the other; but the interior plateaus and basins of this region, consisting of the true coal-rocks, are separated into two nearly independent groups by intermediate valleys of red shale, especially by that which is drained by the head-waters of the Catawissa Creek, and it is expedient to bestow separate designations upon the two portions of the coal-field thus divided. I propose, therefore, to call the Mahanoy and Shamokin basins, and their branches, the Western Middle Coal-field; and all the elevated area of the coal conglomerate and Coal-measures situated N. of the Quakake Valley, N. and E. of the valley of the Catawissa, and S. of the valley of the Nescopeck, the Eastern Middle Coal-field.

The carboniferous district of Eastern Pennsylvania contains centrally within it, therefore, four great coal-fields or groups of coal-basins.

1st. The Southern, or Pottsville coal-field.

2d. The Western-Middle, or Mahanoy and Shamokin coal-field.

3d. The Eastern-Middle, or Upper Lehigh coal-field.

4th. The Northern, or Wyoming and Lackawanna coal-field.

Indeed, ample mention has already been made in Chapter III. of the Introductory Book, Part II., of their mineral nature, and their measured thicknesses around and within both the anthracitic and bituminous coal-fields of the State, enabling any one to deduce their characters and dimensions for intermediate localities not enumerated, and affording all the requisite data for any scientific conclusions that the present state of geology can suggest concerning the quarters whence their materials were derived, and the physical conditions under which these were deposited, and supplying, moreover, all the elements of a practical or technological interest. But full as this synoptic statement is, it seems expedient to introduce here a special description of the Vespertine and Umbral rocks of the anthracite country.

DESCRIPTION OF THE STRATA.

In the carboniferous district embracing the anthracite fields, and, indeed, in the much more extensive region of the bituminous Coal-measures, the only rocks at or near the surface, besides those of the coal formation itself, are the Vespertine sandstones and the Umbral red shales. A careful comparison of the organic remains of the three formations has demonstrated that they are equivalent or parallel deposits to the three great subdivisions of the carboniferous system of Europe. The Vespertine rocks correspond apparently to the European lowest carboniferous formation of the yellow sandstones of Ireland; the Umbral series is the near equivalent of the carboniferous limestone and its associated strata; and the anthracite coal-measures seem strictly on the horizon of the great coal-formation of England, France, and Belgium. It is proper, therefore, that the three series should be grouped together, and described in the same division of this work, and the expediency of this treatment is confirmed by their close geographical connection.

Vespertine Series around the Anthracite Basins.—Both this formation and the Umbral have received a general description in the Introductory Book to Part II., where not only their composition, but their distribution and changes of type and thickness, have been systematically stated.

In its S.E. development, or surrounding the S. coal-field, the Vespertine formation consists, as already described, of grey and yellowish sandstones, with beds of coarse silicious conglomerate, and of dark-blue and olive-coloured slates. Like nearly all the coarser mechanical strata of the Appalachian Chain, it is both thickest and coarsest towards the S.E. or E., and it shows a marked gradation in these respects between each of its successive outcrops. Thus, while its first outcrop displays at Pottsville a thickness of 1800 feet, and at the Susquehanna of 2000 feet, its outcrop in the Nescopeck Mountain shows a reduction of dimensions to 1100 feet ; and still further N., in the mountains enclosing the Wyoming coal-field, a further reduction to only 500 or 600 feet. In accordance with this change of dimensions, it undergoes a corresponding alteration from the coarse type we have assigned it in its Southern outcrops, to that of an argillaceous greenish-grey sandstone, and interstratified reddish olive-coloured shales, in its Northern.

At Mauch Chunk, where its total thickness is about 1300 feet, the first or lowest 500 feet consist, in ascending order, of

Olive-coloured shale, ...	66 feet.
White silicious sandstone, ...	60 „
Fine-grained grey sandstone with large fracture, ...	374 „

The middle and upper divisions are here composed of alternations of coarse conglomerates, and grey and bluish coarse and fine-grained sandstones, embracing thin beds of olive and black slate. At the base of the formation there occurs a thick alternating group of beds of grey sandstone, some of them pebbly, and beds of argillaceous red sandstone and red shale, identical with the Ponent series. This is a passage-group between the Ponent and Vespertine, not referable to either formation exclusively. The few obscure organic remains discovered in it are stems of *Lepidodendra* imbedded in the grey sandstones, relating these beds to the Vespertine series. This transition-group has an average thickness of 600 or 700 feet.

At Pottsville this intermediate mass consists, in the ascending order, of the following beds :

1. Grey sandstone with a little conglomerate, surmounted by a dull reddish sandstone, 72 feet thick.

2. Greenish-grey sandstone and olive-coloured micaceous sandstone, including some beds of conglomerate, and succeeded by hard red sandstone, and this again by softer red argillaceous sandstone, 56 feet.

3. A hard dull-red sandstone, a speckled grey sandstone, and layers of red shale, 62 feet.

4. Argillaceous sandstone conglomerate, composed of slate and sandstone pebbles, and a hard red sandstone imbedding pebbles of quartz and slate, 197 feet.

5. A coarse grey sandstone, 120 feet.

6. Yellowish sandstone, with pebbles of slate, coarse grey sandstone, and a dull-red sandstone, 180 feet.

The total thickness of the group is 687 feet.

On the Susquehanna this alternating series, composed of very similar materials, has a thickness of about 525 feet.

The Vespertine conglomerate includes at Pottsville the following subdivisions in the ascending order :—

1. Coarse compact sandstones, and a brownish-red sandstone, 196 feet thick.
2. Speckled grey sandstone, olive-coloured micaceous sandstone, and compact purplish micaceous sandstone, 213 feet.
3. Coarse grey sandstone, with a little conglomerate, 240 feet.
4. Fine and coarse conglomerate, and hard compact greenish-grey sandstone, 162 feet.
5. A coarse hard yellowish and micaceous sandstone, with some conglomerate, 163 feet.
6. Coarse and fine conglomerate, with hard coarse grey sandstone, 109 feet.
7. Coarse grey micaceous sandstones and coarse conglomerates alternating, 292 feet.
8. Bluish-black micaceous slate 22 feet.
9. A coarse grey sandstone, succeeded by a very coarse harder variety, and this surmounted by a conglomerate of rather small quartz pebbles, 68 feet.
10. Coarse sandstone and conglomerate, 296 feet.
11. Hard greenish-grey sandstone, overlaid by coarse grey micaceous sandstone and beds of silicious conglomerate, 32 feet.
12. Grey sandstone and fine-grained conglomerate, 25 feet.

The last-described or upper beds of the formation, are at the N. foot of the Second Mountain, and the alternating series beneath commences a little below the bridge over the Schuylkill.

Leaving the S. outcrop of the Vespertine conglomerate, and advancing N.W. across the anthracite basins, we observe that the formation maintains very nearly the aspect and composition which it has in the Mahoning or Second Mountain, the most important change being a progressive declension in thickness and a gradual reduction in the coarseness of the conglomerates and sandstones, and an increased proportion of argillaceous matter. The same modifications are apparent in the intermediate group of strata which connect this formation with the Ponent series below it. In the Nescopeck and Shickshinny mountains these possess a thickness of less than 400 feet, and include fewer beds of coarse sandstone and conglomerate.

Umbral Red Shale around the Anthracite Basins.—This group of strata, occupying the immediate place in the general series between the Vespertine sandstone and Seral or coal conglomerate, surrounds all the coal-basins, the chief part of the formation appearing in the deep and regular valley immediately outside of the conglomerate which bounds the Coal-measures. The lower beds rest against the foot and on the lower slope of the ridges composed of the Vespertine conglomerate, and the upper strata dip beneath the Seral conglomerate high on the flank of each ridge of that formation. Throughout the Anthracite district the whole red-shale formation is remarkable for great sameness of character in its different parts, and for little variation, except in point of thickness, in the different belts along which it is exposed. In lithological composition it bears a very close general resemblance to the main body of the Ponent red shales and sandstones. Neither stratum is characterised by the presence of more than a very few organic remains. These, where they are met with, will readily serve to distinguish the two formations, the fossils of the Ponent series being for the most part bivalve shells and Encrini, while the few forms found in the Umbral red shales belong almost exclusively to plants, but not to species or even genera identical with those of the Coal-measures.

The Umbral red shale consists, throughout its S.E. and middle belts, of very argillaceous red sandstones, alternating with red shales. In the vicinity of the Schuylkill these two rocks are associated in very nearly equal proportions, but as we advance Eastward upon the first or most Southern line of outcrop, the silicious or sandstone members predominate more and more. Everywhere the lower portion of the mass contains a preponderance of tough grey micaceous sandstone; the middle and upper divisions possess a larger share of soft red argillaceous beds, with occasional interstratified grey sandy shales, all alternating with red and grey argillaceous sandstones. This character extends to within a few hundred feet of the bottom of the overlying coarse strata of the Seral conglomerate, the intervening mass, referred for convenience to the Vespertine formations before us, consisting of an alternation of red shales identical with those of the Vespertine and coarse grey sandstone resembling the Seral group.

Of the red sandstone we may distinguish three varieties, differing in colour and hardness—1st, A florid red rock, rather soft; 2d, A brownish-red rock, more common than the preceding; and, 3d, A dull or greyish red, the hardest of the three. Many of the sandstone strata are delicately subdivided by alternate bands of different shades of colour, imparting to the smoothed or dressed surfaces a pleasing aspect. Those varieties which are not too argillaceous to withstand the attacks of weather, and are possessed of the softer and more neutral shales of brown and grey, seem well adapted for the purposes of architecture, and the time cannot be distant when their suitableness and beauty will cause them to be chosen in many places as preferable to common brick for buildings. Some of the grey silicious sandstones of the middle and inferior parts of the formation, though less attractive in their tints, are perhaps better fitted for certain architectural uses, being of a more durable composition, and yet susceptible of being readily shaped.

The more argillaceous varieties of the red shale frequently contain a small proportion of the carbonate of lime, and in a few localities there are even one or two thin bands of a very argillaceous limestone, not pure enough, however, for conversion into lime. In these layers of calcareous shale the greater part of the carbonate of lime is in the form of small oval concretions, seldom half an inch in length, looking like yellowish-white pebbles. By the dissolving action of the rain-water upon these calcareous concretions, the rock generally exhibits its external surface deeply pitted, the long-weathered portions wearing a singular worm-eaten aspect. Several such belts may be seen at Mount Carbon immediately S. of the hotel. These calcareous bands occur in the upper part of the formation, but in the middle and inferior parts of the mass such layers are more frequent and usually thicker. As many as twelve distinct beds are met with near Tamaqua. One of these is 6 feet thick, but the little nodules of limestone are rather thinly scattered; another is about 3 feet thick, and embraces the nodules in great abundance. The foregoing description is applicable more especially to all the Umbral red shale surrounding the Southern and central anthracite basins. The only quarter where there is any important addition to this type is in the belt encircling the Wyoming basin. There, though the red sandstone and red shale are still the prevailing rocks, they embrace much greenish silicious shale and grey calcareous sandstone. Towards the W. end of the basin these rocks are confined chiefly to the uppermost part of the formation, but as the belt stretches N.E. they augment rapidly in quantity, and alternate with the red portions in the body of the formation.

Around the border of the Wyoming coal-basin the Vespertine rocks undergo a considerable change of composition and thickness, as may be seen by consulting the sections and vertical columns illustrating that region. I here present them as they occur at Solomon's Gap—a good central locality—that the reader may contrast them with their S. type, already given.

It is only in its S.W. outcrops—namely, in those around the bituminous coal-basins in Somerset, Westmoreland, and Fayette—that any continuous masses of limestone occur in the Umbral series, and even there this rock is of subordinate importance when compared with its enormous development in Virginia and in the Western States. In the anthracite district before us we have both the Vespertine and Umbral formations under their extreme Eastern or *littoral* types, and therefore the calcareous ingredient, a *marine* characteristic, is in its minimum development. Indeed, in the outcrops surrounding the anthracite basins, no genuine limestone presents itself in the Umbral red shale, and the great body of the formation is singularly destitute of calcareous matter in even a more diffused form.

Geographical Range of the Vespertine Sandstone and Umbral Red Shale.—The Vespertine and Umbral formations may be traced encircling all the anthracite basins in a nearly continuous but very winding belt, the Vespertine forming an unbroken mountain-girdle, and the Umbral a deep and narrow valley between it and a parallel and similar mountain-barrier, composed of the Seral conglomerate, which constitutes the immediate rims of the coal-basins. If we follow the line of outcrop of the Vespertine sandstone from it S.E. extremity, Westward round the coal-fields, we shall find it to coincide with the crest and inner flank of the Big Creek or Kettle Mountain, East of the Lehigh, and to form the entire anticlinal mass of the Nesquehoning or Broad Mountain East of the Little Schuylkill. Tracing it from the Lehigh, it forms the main or N. summit and the N. slope of the Second or Mahoning Mountain, with a steep N. dip the whole distance into Perry County, where it curves suddenly round towards the E. to enclose the beautiful red-shale valley called the "Cove." In this turn the Vespertine and Umbral rocks enclose the W. end of the Dauphin coal-basin. Recrossing the Susquehanna with a S. dip, it stretches E., forming Peter's Mountain, and folds round and over the great anticlinal of the Short Mountain, and, resuming a N. dip, becomes the ridge known as Berry's Mountain. It once more crosses and recrosses the Susquehanna, forming between it and the Juniata another synclinal cove of the Umbral red shale, usually called Hunter's Valley. In this synclinal trough the Vespertine and Umbral strata encircle the W. end of the Bear Valley, or Wiconisco coal-field. E. of the Susquehanna it forms the Mahantango Mountain, with a S.E. dip. The formation then bends suddenly W., folding over the great anticlinal of Mahantango Valley, and extends W. again in the Line Mountain as far as the Susquehanna, which, in this third W. bend, it does not cross. By another sudden flexure at the river, the formation sweeps again towards the E., and constitutes the long ridge called the Mahanoy and Little Mountain. This curve marks the termination of a third synclinal trough in the Vespertine and Umbral series encircling the W. end of the Shamokin coal-basin. A third great anticlinal, that of Roaring Creek Valley, causes the Vespertine conglomerate to change again its direction, and to fold round and bend W. in the ridge called the Catawissa Mountain. Near the town of Catawissa it forms, with the Nescopeck Mountain, a fourth synclinal trough, ending, as in each of the three preceding instances, in a bold synclinal mountain-knob. Embraced within this last-mentioned trough of Vespertine and Umbral rocks are the small coal-fields of M^{c}Auley's Mountain and Black Creek. The Vespertine formation now ranges E. along the Nescopeck Mountain to the sources of the Lehigh. Here it flattens in its dip, and, expanding, overspreads—except near the anticlinal axis—the great flexure of Montour Ridge. Assuming a N. dip, it becomes the Wyoming or Moosic Mountain, the outer S.E. barrier of the Wyoming coal-basin. In the synclinal knob of the Shickshinny Mountain it makes a fifth sweep to the W., enclosing the W. end of the Wyoming coal-basin, and from this point it ranges N.E. in the Shickshinny and Lackawanna Ridge, forming the N.W. barrier of the coal-field until, this outcrop meeting the S.E. one, the two encircle the N. termination of the coal valley in Wayne County. Thus it appears that the Vespertine rocks of the anthracite region form by their W. outcrops five very symmetrical parallel synclinal basins, receding obliquely E. as they advance from S. to N. To the E. of the Lehigh the Vespertine sandstone expands in a wide tract in the general plateau of the Pokono Mountain, the W. part of which it entirely occupies. Uniting there with the more steeply-dipping belts of the Mahoning and Nesquehoning mountains on the S., and with that of the Nescopeck on the N., this broad outcrop completely encloses within it the E. extremities of all the Lehigh coal-basins, embracing between itself and them valleys of the Umbral red shale.

It is not necessary, after the account here given of the range of the Vespertine sandstone, to trace, with a corresponding minuteness, the outcrop of the Umbral red shale. It will suffice to state that, being the middle member of the three carboniferous formations, its monoclinal outcrops occur invariably between those of the underlying Vespertine sandstone, and those of the overlying coal conglomerate. The lower portion of the formation follows the Vespertine sandstone in all its windings and reaches, and usually outcrops high on the inner or synclinal slopes of the ridges formed of that rock. On the other hand, the upper part of the series conforms itself to the outcrop of the Seral conglomerate, ranging at a high level along the outer slopes of the mountain-barriers with which this rock rims in the several coal-basins, and penetrating all the anticlinal coves and nooks which insert themselves between the synclinal knobs or spurs that terminate the lesser troughs of the coal-formation. In a few localities, as at Mill Creek, on Broad Mountain, and in the Eastern Middle Coal-field, the Umbral red shale emerges to the day in slender oval anticlinal patches, encircled by the coal conglomerate, but not accompanied by any outcrop of the Vespertine sandstone.

The breadth and depth of the valley occupied by the easily-excavated Umbral red shale depend upon several circumstances,—the softness of the mass contrasted with the power of resisting watery erosion possessed by the two hard formations which enclose it, also its relative thickness, the steepness or flatness of its dip, and the presence or absence of subordinate flexures at its outcrop. Adjoining the Southern and Western Middle Coal-fields, it forms almost everywhere a monoclinal valley a mile or so in breadth between the crests of the confining ridges, but narrow in its bed, and steeply curving in its slopes. Surrounding the Wyoming coal-field, this valley is very narrow, and throughout the Northern half of the basin degenerates into little more than a bench or terrace, high on the interior slope of the encircling mountains.

It will be expedient to postpone any general view of the composition and geographical distribution of the Vespertine and Umbral strata connected with the bituminous coal region of the State, until we approach the systematic description of that great group of basins; but in the following sketch of the coal-rocks the description will embrace those of the Western as well as those of the Eastern Coal-fields, for the sake of a clearer demonstration of their identity of origin, and their ancient geographical connection.

GENERAL VIEW OF THE SERAL SERIES OR COAL STRATA OF THE STATE.

The next group to be described consists of the *Coal Rocks*, the last or highest division of the great Appalachian system of strata succeeding immediately upon the Umbral series.

These strata constitute by far the most valuable portion of all the mineral deposits of Pennsylvania, and confer upon it an amount of accessible wealth surpassing that of any other commonwealth of the Confederacy, or that, indeed, of any equal country on the globe.

While they thus surpass in commercial value, acre for acre, every other group of strata, they also cover a far larger territory than any other formation within the State.

The truly gigantic scale upon which the coal-fields of Pennsylvania are modelled, gives to this portion of her geology peculiar claims to the attention, not merely of the geologist, but of the capitalist and the statesman.

By enabling the geologist to trace the same coal-seams and other strata through their modifications of type, this great horizontal expansion of the formation supplies him with important data for a sound theory of the physical conditions under which the coal originated.

To the capitalist it furnishes the assurance of an inexhaustible supply of the two varieties of raw material which must henceforth exceed all other substances in commercial and industrial influence, *Coal*, the greatest instrument of discovered mechanical or motive power; and *Iron*, the most variously useful and most indispensable of the inorganic bodies which the Creator has bestowed on man. To him it therefore exhibits a field for mining and manufacturing enterprise of almost unlimited scope and future growth.

To the statesman this display of the pre-eminence of Pennsylvania in mineral wealth, cannot but be viewed with the deepest interest, as it must appear to him by far the largest element in the problem of her future industrial, social, and political career.

The detailed examination of the coal-fields of the State engrossed, therefore, a very important share of the labours of the Geological Survey from its commencement to its recent close; and the facts collected, both special and general, are proportionably numerous. The better to enable the reader to grasp the extensive and complex body of descriptive details called for by the objects of the Survey, I shall commence my systematic account of the coal-formation of the State with a brief general outline of its composition and boundaries, and shall then recount more in detail the structure and contents of each particular coal-field or basin.

COMPOSITION OF THE COAL STRATA.

The coal-formation of Pennsylvania embraces a very great variety of strata, extending to nearly all the prevailing forms of sandstone, slate, limestone, and coal. These materials may be ranked under the following three classes of sedimentary deposits—namely, *Rocks of Mechanical, of Chemical, and of Organic or Vital origin.*

The coal strata of *Mechanical origin* are coarse heterogeneous conglomerates, chiefly of quartzose grains and pebbles, silicious and argillaceous sandstones of all grades of coarseness and fineness of grain, and composed of sand and clay in all degrees of mixture ; and a great variety of carbonaceous slates, clay-shales, and grey and purplish-coloured marls. The coarser and more silicious of these deposits prevail most in the inferior part of the series, where massive beds of conglomerate and silicious sandstone occur, both interstratified with the lower coal-beds and underneath them. It is only among the higher strata of the formation that the calcareous shales or variegated marls make their appearance, and the geographical range of these is restricted to the more central tracts of the great basin of the Western side of the State, or that of the Ohio River.

The *Chemically*-derived coal-rocks are limestone, chert, and iron ore. Some of the limestone-beds consist of nearly pure carbonate of lime, some contain also carbonate of magnesia, while others embrace, besides these two ingredients, a large admixture of argillaceous and silicious matter. All the limestones give proof of having been deposited in very tranquil water, for their sandy and argillaceous particles are very evenly incorporated, and almost impalpably fine. These beds of limestone exist only in the middle and higher parts of the series, and they are confined to the bituminous basins, having indeed but little development, except in the main Western one of the Alleghany River. In the anthracite measures, which are the most Eastern of all the coal strata, no limestone whatever appears. Many of the thicker of the Western calcareous coal strata consist of alternating layers of limestone and soft marly shale.

Chert occurs in two or three positions below the middle part of the series, in continuous beds of very considerable horizontal area, but only in the bituminous basins, and chiefly in the main Western one. One of these masses of chert is, for the most part, in contact with a bed of limestone, of which, indeed, it forms almost a portion, the two materials appearing to have been precipitated in immediate succession from the same waters.

Argillaceous Iron Ore is another constituent of the coal strata to which a chemical origin is attributable. It occurs as the *carbonate* of iron, usually in courses or bands of nodules enclosed in the softer shales, and especially in the fire-clay which underlies almost every seam of coal. The ore likewise exists in continuous though thin layers, particularly when in contact with one of the deposits of limestone.

Interstratified among these various deposits are the seams or beds of the *coal* itself, a product of neither mechanical nor ordinary chemical action, but of *Vital* agency, namely of vegetation. These seams are of all degrees of thickness, from a few inches to many feet. This valuable material, coal, is found within the limits of the State in nearly all its known varieties—in some districts under the form exclusively of compact anthracite, in others under that of a very fusible bituminous coal, and in others, again, exhibiting every intermediate proportion of bitumen which it is possible for coal to contain. The place of the principal coal-seams among the extensive group of strata composed of the foregoing varieties, is towards the middle of the formation, neither the very lowest nor the highest portions containing any extensive seams of sufficient thickness to be valuable.

Area and General Distribution of the Coal Strata.—The Coal-measures within the limits of Pennsylvania cover an area of about 12,623 square miles, or not much less than *one-fourth* of the whole surface of the State. They occupy two distinct regions, one of which contains only anthracite, or non-bituminous coal, and the other only the Levant bituminous varieties. The superficial extent of the bituminous coal-measures greatly surpasses that of the anthracitic strata. With one partial exception, the two sorts of coal do not coexist in the same basin, nor indeed in the same region.

The positions of the several anthracite basins have been already defined; the more precise limits of each will be traced in future chapters.

We now proceed to sketch the general boundary of the vast area occupied by the bituminous coal strata.

Limits of the Bituminous Coal-Measures.—Almost the whole of the bituminous coal of Pennsylvania lies to the N.W. of a line following the main crest or escarpment of the Alleghany Mountain from the Maryland State line to the Susquehanna, thence up the river to the Sinnemahoning, and up this latter stream to the sources of Trout Run, extending thence North-westward to Warren, and from Warren W.S.W. by the course of the Alleghany River to Franklin, and from Franklin to the Ohio State line at Sharon, in Mercer County. On the W. the limit is the State line of Ohio, and on the S. it is that of Virginia.

Besides this great and almost unbroken coal-field, there are several insulated tracts outside of the boundary here drawn. One of these is the Wills' Creek basin, in the S.E. corner of Somerset County, the part in Pennsylvania being but the extremity of the Potomac Basin of Maryland; another is the coal-field of the Broad-Top Mountain in Bedford; a third, that of Towanda Creek in Bedford; a fourth, that of Blossburg in Tioga. All of these are destined, from their positions to markets, to be hereafter of much value in the coal or iron commerce of the State.

There are several other smaller detached patches of the coal-formation in Luzerne, Lycoming, Tioga, Potter, and M^cKean counties, but these are of less relative importance. I reserve for a subsequent Chapter a more exact delineation of the limits of the coal strata both of the great Trans-Alleghany coal region, and the smaller outlying tracts to the E. and N.

Within the general boundaries sketched above, the coal strata almost everywhere underlie the soil. The only tracts where other formations emerge and subdivide the coal region, are the summits and slopes of the long narrow anticlinal ridges, the Negro Mountain, Laurel Hill, and Chestnut Ridge, except, indeed, on the Northern and North-western edge of the district, where, as in the neighbourhood of the Sinnemahoning, the same lower strata intrude a little within the general boundary. The coal-formation, therefore, occupies nearly the whole of Somerset and Cambria, the greater part of Clearfield, a corner of Clinton, one-half of Elk, the chief part of Jefferson, a corner of M^cKean, and the adjacent corner of Warren, a part of Forest, nearly all of Venango, and of Mercer and Lawrence, besides the entire surface of Clarion, Indiana, Armstrong, Butler, Beaver, Alleghany, Washington, and Green, together with nearly the whole of Westmoreland and Fayette counties.

Ample as this wide area of our inexhaustible deposits of fossil fuel appears, it constitutes but a small portion—only the N.E. extremity, indeed—of a coal-field of much more stupendous size, the great Appalachian basin, extending continuously to Alabama, the largest and richest coal region on the globe.

This enormous coal-field, beginning at the N.E. in Pennsylvania, as already shown, ranges South-westward through Ohio, Virginia, Maryland, Kentucky, and Tennessee, and only terminates in the interior of Alabama. Its total length is about 875 miles, and its greatest width, measured from the escarpment of the Alleghany Mountain to Akron in Ohio, is about 180 miles. I estimate it to cover very nearly 70,000 square miles, and to constitute more than *one-third* of the total known area of coal strata in the world. As the central or deepest portion of this prodigious basin coincides nearly with the "Long Reach" of the Ohio River, between Marietta and the mouth of Fishing Creek, it is obvious that the South-western counties of Pennsylvania are situated far enough within the trough to embrace the coal-formation in nearly its greatest thickness, and I have ascertained that only one or two valuable coal-beds, the very highest in the basin, fail to enter the State. The chief of these is the Carr's Run, or Pomeroy Seam, so extensively and profitably mined on the Ohio River.

CLASSIFICATION OF THE COAL ROCKS, AND THEIR MODIFICATIONS OF TYPE.

CLASSIFICATION.

The Coal-formation of Pennsylvania, especially under its Western development in the great Appalachian Basin, demands a fivefold subdivision. The strata naturally group themselves in the following sets or sub-formations :—

1. Seral Conglomerate.
2. Older Coal-measures.
3. Older Coal-shales.
4. Newer Coal-measures.
5. Newer Coal-shales.

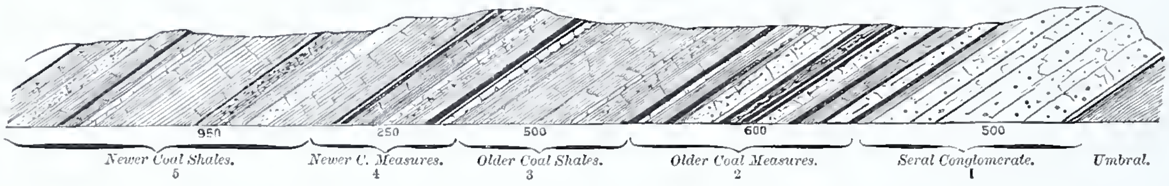


FIG. 137.—Subdivisions of the Coal Series of Pennsylvania.

I.—THE SERAL CONGLOMERATE.

General Characters.—This well-characterised and widely-distributed member of the Coal series consists, in its ordinary or typical condition, of grey and whitish quartzose conglomerate in massive beds, alternating with grey and yellowish sandstone. In many districts it includes one or more thin seams of coal. In the anthracite region it is a very heterogeneous deposit, consisting of thick and ponderous sheets of an extremely coarse, firmly-cemented, and massive rock of quartzose, and other pebbles, of all sizes, from the smallest to that of a hen's egg; of coarse grey sandstones, sandy shales, rough coal-slates, and even in some quarters thick and valuable beds of coal; but this diversity of composition grows less as it passes Westward beneath the bituminous basins. There the pebbles are smaller, and the rock has rather the aspect of a coarse silicious white pebbly sandstone than that of a conglomerate, and its parts cohere much less closely. A full synoptic account of this member of the Coal series, in all its modifications of composition and thickness, has already been given in the Introductory Book, Chapter III., page 146. From that exhibition of its various types, we can see at a glance its remarkable gradations as it spreads toward the N. and W. It is an extremely persistent deposit, and accompanies the Coal-measures of the great Appalachian basin everywhere, not merely in Pennsylvania, but throughout the other States to the S.W., forming invariably their floor. As it thus underlies both the anthracite and the bituminous Coal-measures, and in fact alternates intimately with their lowest coal-beds, it establishes conclusively the identity in age and origin of these two externally dissimilar sets of Coal-measures. That it is properly itself a subdivision of the Coal-measures is shown in its containing regular and even thick beds of the coal, identical in composition with the seams of the generally productive overlying group, and also in its enclosing innumerable genuine fossil coal-plants, especially the fragmentary stems of Lepidodendra, Sigillaria, and Ferns.

II.—LOWER COAL-MEASURES.

Anthracite Region.—It has just been intimated that the older or lower division of the Coal-bearing strata rests directly on the Conglomerate, and that the two are indeed closely united by an alternation of their contiguous beds. It is, therefore, impossible to assign a well-defined permanent horizon of separation; but considerations of convenience dictate that we place an arbitrary boundary at the bottom of the first or lowest considerable coal-seam. The upper limit of the older coal group is entirely arbitrary in the anthracite basins, but considerations of convenience dictate that we place it in the rocks which immediately underlie the great Mammoth seam of the Pottsville district. The anthracite Coal-measures embrace the following classes of strata :—

1. Coarse grey micaceous sandstones, and near their lower limits a few massive beds of conglomerate.
2. Grey and bluish argillaceous sandstone.
3. Compact blue slate, frequently covering the coal-beds, and also occurring in independent strata.
4. Blue compact shale of rather fine texture, having frequently an irregular and splintery fracture, and containing rootlets of Stigmaria. This is the prevailing floor of the seams of coal ; it is a somewhat coarse or silicious fire-clay.
5. Beds or seams of anthracite coal.

The slates and shales of the anthracite measures are, on the average, more silicious and sandy than the argillaceous deposits of the bituminous basins. Some of these shales are very slightly calcareous ; but in all the anthracite basins there is not *one bed, however thin, of true limestone.*

Particular layers of the blue argillaceous shale contain nodules of *clay iron-ore,* or argillaceous carbonate of iron, in more or less well-defined courses. This species of ore, so general an accompaniment of coal shales in all parts of the world, chiefly abounds in the *lower* portion of the lower anthracite measures ; it is plentifully met with, and purest, in the under shales or fire-clays of the coal-beds. Throughout all the anthracite basins the ore, as a general rule, is more silicious in its composition than that of the bituminous measures W. of the Alleghany Mountain, and the surrounding shale adheres more firmly to the nodules, causing an increase of labour and expense to cleanse them for the furnace.

Thickness.—To estimate the total thickness of the older anthracite measures is not easy, owing to the impediments to exact measurement from contortions of the strata and extensive dislocations intersecting the formation.

Along the Southern side of the Pottsville Basin the strata of this group, ranging in the

Northern slope of the Sharp Mountain, have their thickness obscured by an excessive squeezing of the coals and softer measures. We must have an estimate, therefore, on measurements of the formation on the Northern side of this basin, or on data collected in the other coal-fields. The total thickness of the Coal-measures of the Pottsville Basin on Silver Creek is about 3000 feet, measuring from the upper beds of unproductive conglomerate to the synclinal axis at the Schuylkill. Of this mass, about 967 feet lie below the Skidmore seam, or belong to the lower White-Ash group; 330 feet represent the upper White and Grey Ash group, ending with the Black Valley coal; and about 1261 feet, the Red-Ash series to the Peach Mountain bed inclusive. In other districts the relations of these several groups in respect to thickness, and the number and dimensions of their included coals, will be very different, so that no general statement can be given which will fairly express their average development in the anthracite country; but the above will serve as one instance. The various sections and details to be hereafter presented will offer many more.

Many of the coal-beds of the inferior group have a thickness which is truly extraordinary, and this is not local, but belongs to them throughout their entire line of outcrop in all the anthracite basins. Each of these basins contains two or more great beds of coal which surpass in size any others known in North America, and rival the thickest in the world. The larger beds are in some districts from 25 to 30 feet thick, and by the occasional thinning-out of the intervening rocks, two or more thick seams sometimes coalesce and form one of still greater dimensions.

The Older Bituminous Coal-measures.—The strata present features which deviate somewhat from those of the lower anthracite group. The conglomerates of the lowest anthracitic seams are in the Western or bituminous basin represented by coarse silicious grey and yellowish sandstones, containing occasionally a more or less abundant sprinkling of small and well-rounded quartzose pebbles, imparting to them a partially conglomeritic character. These sandstones derive their yellowish stain from the hydrated peroxide of iron. Similar sandstones fill up a portion of the wider intervals between the coal-beds throughout this older group. These arenaceous strata, more especially the inferior ones, are the main reservoirs of the *brine*, which is tapped by the artesian borings at so many localities in the bituminous region. Either the older anthracitic conglomerates and sandstones were never impregnated with salt as these were, or their more crushed and uplifted condition has caused it to filter away to inaccessible depths; or what is more probable still, the steaming which the anthracite Coal-measures underwent during their metamorphism has exhaled the chloride of sodium which they contained.

As a general rule, the sandstones of the older bituminous measures are much softer, finer-grained, and more argillaceous than the arenaceous rocks of the anthracite. The shales and slates are less sandy, and have a finer texture, and the fire-clays are more purely argillaceous; but the most striking distinction is the absence of limestone and calcareous matter in the anthracitic regions, and their frequent presence in the bituminous. These constituents of the strata progressively augment in the older Coal-measures as we advance Westward from the Alleghany Mountain; the shales become steadily more calcareous and marly, and the beds of limestone thicker and more numerous. In the main Western basin there are usually three deposits of limestone, distinguishable not only by their aspect, but, wherever they are fossiliferous, by their organic remains. It is in this lower group of coals that one of the principal beds of chert occurs. Here likewise are nearly all the layers of iron ore which belong to the bituminous Coal-measures.

The *thickness* of the older bituminous measures in the district of the Alleghany River is apparently about 600 feet.

III.—OLDER COAL-SHALES, OR LOWER BARREN GROUP.

Between the lower and upper Coal-measures there is interposed a group of strata which in the bituminous region contains no coal-seams of notable dimensions.

In the anthracite basins this barren group of Western Pennsylvania is not recognisable. Indeed, it has not been possible, after very patient study, to co-ordinate the individual coal-beds, or the different groups of the coal-measures of the bituminous coal-field, with those of the anthracitic. In the Western coal-fields this group includes not only several thick strata of soft argillaceous sandstone, but various deposits of red, yellow, and blue calcareous shale or marl, and two or three unimportant beds of argillaceous limestone. The coloured aspect of these shales, some of which are brightly tinted, enables the observer at once to recognise them, and to ascertain his place in the formation. This feature grows more and more conspicuous as we advance from the Alleghany Mountain westward into Ohio. The limestones likewise augment in thickness in the same direction, being in the basins near the Alleghany Mountain only a few feet thick, but amounting at Pittsburg to about 30 feet. Their position is near the top of the group. This lower barren group has for its inferior limit the top of the Upper Freeport coal, and for its superior boundary the bottom of the great Pittsburg bed. About 300 feet of its upper strata are visible near Pittsburg, between the level of the Monongahela River and that of the main coal-seam of the district.

Very little iron ore occurs in this division of the coal series. Some of the layers of limestone contain interesting and distinctive species of fossil shells, corals, and other remains indicative of a marine origin for some parts at least of the formation.

IV.—UPPER OR NEWER COAL-MEASURES.

Above the older Coal Shales of the Bituminous Coal-measures of the main Western basin there occur several seams of coal, the two lowest of which, the Pittsburg and the Waynesburg beds, and occasionally a third, are valuable beds.

The first of these is a deposit of very great value.

For the sake of convenience I have grouped together these uppermost workable beds under the name of the Upper or Newer Coal-measures. That part of the formation which embraces them, measuring it from the bottom of the Pittsburg coal to the top of the Waynesburg seam, has an average thickness of from 200 to 240 feet. It consists in the more Eastern bituminous basins of argillaceous sandstones, calcareous shales, and thin layers of limestone; but as we pursue it Westward across the Monongahela to Wheeling the sandstones progressively fade away, the shales become more calcareous, and the limestones greatly increase, until these two latter kinds of rock constitute on the Ohio River the principal materials. In this portion of the series we meet with almost no clay iron-ore.

It is not easy to determine what portions of the coal series of the anthracite basins represents the upper productive coal group of the bituminous region, nor is it at all certain that any part of the classification natural for the Western Coal-measures will apply to the Eastern. The mutability of all the coal strata on a large scale, shown by the thinning-out and coming-in of the coal-beds and the rocks which separate them in both coal regions, should discourage any expectation of our ever successfully co-ordinating the individual deposits of the two districts, though we are well convinced they were once united and continuous. I shall therefore refrain from a closer parallel between the two sets of strata.

V.—UPPER OR NEWER COAL-SHALES, OR UPPER BARREN GROUP.

It is questionable whether any part of this the uppermost division of the coal-rocks has been preserved from denudation in the anthracite basins, if, indeed, it ever existed there.

The group is distinctly recognised only in the South-western corner of the State, W. of the Monongahela River, and S. of the Ohio. There, in the hills of Green County, the total thickness of the group amounts to between 900 to 1000 feet. It includes four or five thin seams of coal which seldom expand to the thickness of 2 feet, and are therefore of little or no value. It contains also a number of thin beds of limestone, from 2 to 5 feet in thickness, but the chief strata are sandy shales and flaggy micaceous sandstones more or less argillaceous. Some of the shales are calcareous, and when this is so, the overlying soil has more fertility than usually belongs to the group. No iron ore, in any notable quantity, has hitherto been discovered in this part of the formation.

Having in the foregoing sketch given a brief general account of the composition of the coal strata of Pennsylvania, I shall proceed to a detailed description of the several anthracite basins of the Eastern Carboniferous District.

ANTHRACITIC COAL STRATA.

I.—BOUNDARIES OF THE SEVERAL COAL BASINS.

The general limits of the region, embracing the anthracitic Coal-measures, have been already sketched, and it was stated that the area actually covered by the coal-bearing strata is small in proportion to the whole territory within which they are distributed.

An inspection of the geological maps will show that the three long and nearly parallel areas of the coal strata, separated from each other by anticlinal belts of the Middle Palæozoic rocks, are all, if we except the more simple Wyoming Basin, rather groups of synclinal troughs than solitary basins.

The Southern Anthracite Basin, or the Schuylkill or Pottsville Basin, extends from the Lehigh at Mauch Chunk westward between the Locust and Broad mountains on the N., and the Sharp Mountain on the S., in a gently widening valley to the waters of the Swatara, near Tremont, where it separates into two contracting prongs, the N. and shortest of which stretches Westward to its termination as the Wiconisco Basin between the Bear and Wiconisco mountains ; and the Southern, known as the Dauphin Basin, bounded by the Sharp and Fourth mountains, reaches to within 3 miles of the Susquehanna River. Intimately connected with this great basin is the smaller and closely-adjacent coal-valley N. of Mine Hill. This slender trough is called the *Mine Hill Basin.* North of the Mine Hill Basin there are other smaller ones in the Broad Mountain.

The Eastern Middle or Lehigh Basins include the Spring Mountain, the Beaver Meadow, the Pismire Hill, the Hazleton, the Big and Little Black Creek, and the Bucks Mountain basins, besides the small coal-fields of Green and M^cAuley's mountains. This group of *seven* elevated and relatively shallow coal-valleys is bounded on the N. by the Bucks and Green mountains, E. by the valley of the Lehigh, S. by the Spring Mountain, and W. by the valley of the Catawissa.

The Western Middle Group of Basins comprehends those of Mahanoy and Shamokin ; but towards the E. each of these divides into three distinct branches, and thus there are in that quarter six lesser shallow troughs. The whole group is bounded on the N.E. and N. by the valley of the Catawissa and its branches, and more immediately by the ridge of the Big or Shamokin Mountain and the Head Mountain ; S.E. and S. by the valleys of Locust Creek, and the Big and Little Mahanoy creeks, but more immediately by the Broad Mountain and the Mahanoy Mountain. The basins of Broad Mountain are on the high broad anticlinal table-land of that name, between the Mine Hill and the Mahanoy basins.

The Northern or Wyoming Basin is bounded on the N.W. by the general rim of mountain locally known as the Lackawannock, Shawnee, Plymouth, and Nanticoke ridges, and on the S.E. and S. by the Moosic and Wyoming mountains. From the N.E. end of the basin near Carbondale, where the Lackawannock and Moosic ridges unite, it gradually expands, until at Pittston and Wilkesbarre it is nearly 4 miles wide. W. from this central district it again contracts, the N. and S. crests which confine it closing together at Beach Grove, where the Susquehanna cuts across them near their junction. In its general form this, which is the most regular and picturesque of the anthracite basins, is a long crescent-shaped valley, one horn of the crescent pointing N. and the other W.

II.—COMPOSITION OF THE SERAL CONGLOMERATE IN THE SPECIAL TYPE WHICH IT PRESENTS IN THE ANTHRACITE REGION.

In the Anthracite districts, the immediate floor and geographical boundary of the true Coal-measures, is the easily recognised Seral conglomerate. From the fact of its great hardness, compared with that of the argillaceous Coal-measures on its one border, and that of the Umbral red shale on its other, the denuding waters which wore down those soft formations into valleys have left it, especially where its dip is steep, projecting high above them in bold and well-defined mountain-crests or ridges. All the coal basins just defined are therefore encircled by conspicuous natural barriers of this thick and enduring formation.

In its mineral constitution, the Seral conglomerate of the Anthracite is, as already stated, a coarse, rather heterogeneous, but mainly quartzose mass, made up of grey conglomerates, white, grey, and brownish sandstones, and a few thin beds of dark carbonaceous slate, the conglomerates forming the largest and most characteristic portion of the mass. This somewhat diversified structure belongs especially to its more S.E. outcrops ; for traced N.W., especially into the bituminous region, it assumes more and more the simple aspect of a grey silicious conglomerate and whitish sandstone. Its heterogeneous composition is well shown in the first or

Southern basin, especially as it is developed in the Sharp Mountain, where it is not only thickest, but has its greatest complexity of type.

In this outcrop, under an *average* thickness of about 1200 feet, it presents three subdivisions. The *Lower division* embraces—

1. Yellow and grey sandstones, alternating with thin beds of *red shale*, identical with the Vespertine red shale, and containing a few scattered quartz pebbles, some of which are large. This division, which exhibits a passage from the Umbral to the Seral deposits, is from 60 to 70 feet thick.

2. Massive beds of a conglomerate composed of quartz pebbles in a paste of disintegrated green slate. These beds also include layers of red shale. The thickness of this portion is from 10 to 20 feet. In the very lowest bands of this rock, especially those which alternate with, or are imbedded in, the upper layers of the Umbral red shale, this imbedding material is greenish, and sometimes quite yellow. This green tint is due apparently to a mixture of triturated *chlorite slate* or metamorphic clay-slate, chloritic and talcose in aspect, mingled with the sand. These greenish conglomerates of the base of the formation are very beautiful, and were they only of a material which would admit of being dressed or polished, they would be valuable for ornamental uses.

These rocks are well exposed on the back track of the Lehigh Company's chain of roads, especially between the Old Mauch Chunk Tunnel and the crossing of the tracks. In this neighbourhood we have fine exhibitions of some of the coarser beds, and may see masses containing quartzose and sandstone pebbles not less than 5 or even 6 inches in diameter.

Other layers of this lower conglomerate group are more uniformly composed of white quartzose pebbles, but even such beds have their pebbles less closely set and less regular in size than we find them in the layers of the main upper division.

This lower group forms the S. crest and upper steep S. slope of the Sharp Mountain.

3. A coarse silicious conglomerate of large and irregular pebbles, chiefly of milky quartz, but with others resembling the *Primal* and *Matinal* slates; and a few of dark-grey sandstone, of perhaps the same age. Among these pebbles none are found referable to the granitic or gneissic rocks. In some localities the quartz pebbles of these lower strata are of extraordinary dimensions; thus, in the Head Mountain they often exceed 8 inches in their longest diameters. Many of the pebbles in this division of the formation appear to have been derived from the Levant sandstones of the type seen in the Kittatinny Mountain; others seem to have come from the Primal white sandstone.

4. Chiefly yellow and white sandstones, with included layers of a grey grit, composed of pebbles of crushed slate.

The *Middle division* of the formation consists chiefly of thick irregular obliquely-deposited beds of a hard blue rock made up of quartz, sand, clay, and small pebbles of slate. In the Sharp Mountain this part of the formation embraces beds of slate, almost identical with the slates which enclose the coal-seams.

There is also much *oblique deposition* or *false bedding* visible in these sandstones, confirming the evidence afforded by the coarseness of the conglomerates, of the energy of the currents which swept the materials together. From the prevailing direction of the dip of these oblique plains of deposition, we are entitled to infer that the strewing currents moved towards a point a little West of North.

This obliquity of bedding in the conglomerate is conspicuous in all its other outcrops, and it is well worthy of note that in them it usually indicates the same North-westerly movement of the waters implied by the Sharp Mountain beds.

At least one bed of coal, sometimes of a thickness fit for mining, usually occurs in this division. Near the E. end of the basin the thickness of this middle group is probably not less than 200 feet. It is the cause of the flatness of the summits of both the Sharp and Locust mountains throughout the range from Mauch Chunk to the Little Schuylkill.

The *Upper division* of the formation, both in the Sharp Mountain and around the Anthracite basins, generally has a more uniform composition than the beds beneath. Many of the more massive strata are composed solely of large pebbles of white quartz of nearly similar size and shape, packed together with great regularity. These are somewhat ovoid, smooth, or actually polished, and in close contact, their larger dimensions parallel with the plane of bedding. This feature is conspicuous in many of the upper strata of the Sharp Mountain from Pinegrove westward, but from Pottsville eastward a less degree of uniformity prevails. The upper conglomerate is excessively hard to drill, yet it was long ago successfully tunnelled in the Sharp Mountain, by the Lehigh Company, near Mauch Chunk. It generally constitutes the crests of the Sharp and Locust mountains, and often stands forth in a naked rugged wall immediately behind the outcrop of the great coal-bed of the basin.

Where the conglomerate forms the barrier of the Beaver Meadow Basin, both the *Upper* and *Lower* portions contain a somewhat large proportion of argillaceous matter, traceable apparently to the abrasion of the numerous slate pebbles. This argillaceous material, mingled with silicious sand, is the cement in which the larger pebbles are imbedded in some of the less compact conglomerates, which derive, from this slaty matter, their characteristic agreeable green colour.

Of the reduction in the *coarseness* of the conglomerate, as we compare it in its successive outcrops more and more towards the N.W., there is the amplest evidence. Passing from the Sharp Mountain to the Broad Mountain on the N. side of the same basin, there is a perceptible diminution in the pebbles, and an approximation to greater uniformity of size. Another step brings us to the Head Mountain, where one of the lowest beds has a degree of coarseness and irregularity of composition met with in none of the other outcrops; for though the pebbles in the same part of the formation W. of Pinegrove are of great size, they are more regularly oval, and imply a more prolonged attrition. Those of the Head Mountain suggest by their great size and irregular forms, compared with those of other localities, that these were driven by waters endowed with a more than ordinary velocity, moving great columns or streams, pushing violently through the general broad flood while it was dispersing the vast sheet of sand and pebbles.

Advancing to the outcrop of the Spring Mountain, the conglomerate is seen at the notch or gap of Hazle Creek with its pebbles considerably smaller, the beds of slate somewhat thinner and less numerous, and the sandstones and conglomerates less abruptly separated. The pebbles are more even in size, and are packed together with less of interposed sand.

Around the Wyoming Basin, the conglomerate exhibits this modification in a still higher degree, the pebbles there being more uniformly quartzose, and from half an inch to one inch in diameter, and set closer together with but little interposing cement.

While these features of coarseness and irregularity of composition decline towards the N.W., the oblique bedding, the other symptom of turbulence in the waters, likewise progressively abates. All of these instructive changes occur in a distance across the outcrops of hardly 30 miles—much complexity of internal structure being succeeded at this interval by features of uniformity, which approximate to those still more typical characters which the formation retains with such amazing persistency throughout its vast spread beneath the bituminous coal-fields.

Of the gradation in thickness of the Anthracite conglomerate, our measurements already given (see pp. 146, &c., vol. i.) show that the mass has its maximum development in the Sharp Mountain, and diminishes steadily towards the N. and W., but fastest in the W.N.W. direction. In all of the Anthracite basins there is a declension of the thickness from a certain meridian, at least towards the W.S.W.; but this is only a feature of the yet faster thinning towards the quarter above stated.

That this N.W. declension in the thickness and coarseness of the Seral conglomerate, so obvious in the Anthracite region, extends to the bituminous districts, and is in fact a *general law* of the formation, is amply demonstrated in the tabulation already referred to, where its thickness and composition are indicated as far as Tioga County.

In the bituminous coal-field of *Broad-Top Mountain* in Huntingdon and Bedford, the rock exists chiefly as a light-grey coarse silicious sandstone, with but little of the conglomeritic character. At Wray's Hill, on the edge of this high plateau, it measures not more than 250 feet. And this estimate accords well with observations made at other places in the basin. In this district, as in the Anthracite basins, the rock embraces one or more beds of coal, showing that it is as elsewhere a part of the coal-formation.

This basin of Broad-Top Mountain lies not more than 30 miles to the E. of the Alleghany Mountain, the margin of the great bituminous region. In relative position it is therefore a very little more to the N.W. than the Wyoming Valley, and may be viewed as an intermediate station between the Anthracitic and Bituminous coal districts.

Passing to the bituminous basin N.W. of the front ridge or main escarpment of the Alleghany Mountain, the formation, as there developed in the first basin N.W. of the Anthracite region in the *Loyalsock* district, is a white silicious conglomerate, measuring from 60 to 80 feet. On the *Tangascootack*, which is nearly in the same belt, but further towards the S.W., it is a white friable sandstone, sprinkled with small quartz pebbles, and it measures about 100 feet. Along this first belt of basins N.W. of the Alleghany Mountain, the conglomerate generally varies in its thickness from 60 to 150 feet, and exhibits as great a proportionate fluctuation in the coarseness of its ingredients. In some localities it is little else than a white silicious sandstone, while in intermediate places it contains much true conglomerate, in some of the beds of which the pebbles are occasionally an inch or more in diameter.

This local coarseness of the fragments is traceable as far to the N.W. as Bennett's Branch of the Sinnemahoning, and is a further proof, that while the currents which dispersed this submarine drift moved in the manner of a broad sheet of waters, they contained columns of great momentum, as the distance this gravel was transported could not have been *less* than 200 miles, and may have been much more.

Advancing W. from the Alleghany Mountain, the Seral conglomerate undergoes but a trivial further reduction in its thickness, even when traced the whole way across to Mercer and Warren counties.

On Drake's Run, a tributary of the Youghiogheny, it is nearly 100 feet thick, and along the N. and N.W. final outcrop of the formation its average thickness is from 60 to 75 feet, though in some districts it measures not more than 20 feet. It should be observed that not only does the stratum itself thus locally fluctuate, but the measurements are liable to error by embracing sometimes the next overlying sandstones, where the intermediate coal-seam and its slates are either locally absent or concealed by the soil. Indeed, this local interpolation and disappearing of the lower coal-beds, and the consequent dividing and uniting, thickening and thinning-out, of certain strata, would, even if the whole formation were laid open to the day, render it impossible to trace either the whole conglomerate or any member of it, however well defined its boundaries might be at starting, the entire distance, or perhaps one-third of it, across this enormous coal region. We might set out with a perfectly sharp plane of separation between the conglomerate and the underlying red shales, and call this the common boundary of the Seral and Umbral formations, and might follow this limit without ambiguity for many miles ; but upon pursuing it still further, we should inevitably discover that our horizon was becoming uncertain by the wedging-in from the W. of another bed of similar composition, beginning with a mere feather edge, but thickening steadily, while the portion of the red shale insulated between it and the main conglomerate underwent a corresponding thinning in the same direction, until at last the original plane of separation would vanish by the junction of the two conglomerates, and the now visible boundary would be the bottom of the newly-interpolated bed. The cause of this shifting of the horizons of separation between strata, so conspicuous in the carboniferous rocks of Pennsylvania, will be discussed in a future chapter, where the mode of formation of our strata, and the theory of deposition generally, will be specially discussed.

DIVISION I.

DETAILED DESCRIPTION OF THE SOUTHERN OR SCHUYLKILL BASIN.

CHAPTER I.

GENERAL STRUCTURE AND TOPOGRAPHY.

It will be seen, by consulting those portions of the Geological Maps which embrace the anthracite region, that the Southern coal-basin, ranging from the Lehigh almost to the Susquehanna, is far from possessing a simple configuration or structure. It is, in fact, quite irregular, and consists of five separate Districts.

1. *The Lehigh and Little Schuylkill District.*—From its E. extremity near Mauch Chunk, the mountain-ridges enclosing the basin, diverging from their synclinal knob on the Lehigh, called Mount Pisgah, range W., gradually separating, but with no considerable deviation from straightness, and no break of continuity but the simple notches which give passage to the streams as far as the neighbourhood of Tuscarora and Middleport. The structure of this beautiful division of the valley is that of a rather symmetrical synclinal trough, gradually expanding and deepening towards the W., and confined on each side by steep and regular mountain-slopes. The general synclinal form of the coal-field is preserved throughout this tract, though locally interrupted by several subordinate anticlinal flexures. This part of the basin is about 19 miles in length, and widens W. from a mere point to a breadth of 1½ miles opposite Tuscarora. The average dip of the strata in the Sharp Mountain, its S. boundary, is about 80° N. 22° W. That in the Locust Ridge on the other side is between 50° and 60° S. 20° E. The configuration of the W. portion of this part of the basin is well shown in the background of the sketch representing the Lehigh Summit coal-mine.

2. *The Schuylkill and Swatara District.*—The second division of the basin extends from the abrupt expansion of the valley at Middleport to Lorberry Creek N.W. of Pinegrove. This portion is about 22 miles long, and in its central and widest part about 4 miles broad. The Sharp Mountain is its S. boundary, and Mine Hill its N. In the Sharp Mountain the rocks have been uplifted beyond the perpendicular, so that they lean in an inverted position upon the Coal-measures, dipping at a high angle to the S. instead of towards the N. In some places the dip is perpendicular. This condition of things extends from opposite Middleport to near the W. end of the Dauphin branch of the basin. The structure of Mine Hill, on the other hand, is anticlinal. The monoclinal North-bounding ridge, known as the Locust Mountain, ranges W. into the Broad Mountain, while almost in the middle of the synclinal basin, near Tuscarora, rises the Mine Hill southward of the other, and overlapping it by more than half a mile. The anticlinal

crest of Mine Hill ranges on in an almost straight course in a well-defined summit, exposing the Seral conglomerate, and separating the Pottsville coal-field from a smaller basin on the N., which is called the Mine Hill Basin.

The anticlinal structure of Mine Hill, visible at the gaps of Mill Creek, West Branch, and West-West Branch, gradually declines by the flattening of the arch, which still runs on, however, through the W. plateau of Broad Mountain. Nearly opposite the E. end of the Mine Hill, the Sharp Mountain exhibits a remarkable change in the position of its crest, which suddenly shifts to the S. more than half a mile. The offset is marked by the presence of two anticlinal axes, which, originating outside of the coal-field between the Little Schuylkill and the Lehigh, pass W. through the Sharp Mountain, and throw forward two long declining spurs into the coal-basin, one of which subsides E. of Middleport, while the other, known as Silver Hill, lying nearer the Sharp Mountain, ends S. of that village. Between these two anticlinal spurs lies a narrow and shallow trough or cove of the lower coal-rocks, and between the more S. and the flank of Sharp Mountain another longer and deeper one. It is this abrupt shift to the S. of the crest of the Sharp Mountain, and the rising of the Mine Hill on the other side, which nearly insulates the E. division of the basin from the main central portion. The wider middle part of the coal-field contains a number of subordinate anticlinal flexures, some of them of the form of inverted folds in the Coal-measures, several miles in length, besides many local contortions and irregularities of the dip.

3. *The Mine Hill Basin or District.*—The third division of the S. basin is the separate and smaller synclinal trough N. of Mine Hill. It is between 13 and 14 miles long, and from a fourth or half a mile wide at its E. end, to a mile where it is broadest W. of Heckscherville. Its N. boundary is the Broad Mountain, into which, indeed, its two extremities may be said to penetrate. This Mine Hill Basin forks into two branches at its W. end by the intrusion of the Peaked Mountain.

The fourth and fifth divisions of the main coal-field originate in the vicinity of Lorberry Creek, by the intrusion from the W. of a broad anticlinal belt of the Seral conglomerate and still lower rocks, forming the Little Lick Mountain and the valleys W. of it. This causes the basin to separate into two long and narrow synclinal troughs, the more S. of which is called the Dauphin Basin, and the more N. the Wiconisco Basin.

4. *The Wiconisco Basin.*—This division is nearly 17 miles long, and, measuring from one outcrop of the conglomerate to the opposite one, is from a mile and a half to three-quarters of a mile wide, tapering gradually to a point, with a structure very similar to that of the first or Tamaqua division. Its bounding ridges are the Big Lick Mountain on the S., and the Bear or Thick Mountain on the N., each of them of monoclinal structure, their strata dipping about 45° towards the Coal-measures.

An anticlinal axis appears to range along the centre of this trough, at least from Rausch or Klinger's Gap eastward.

5. *The Dauphin Basin.*—The Dauphin Basin, commencing at Fishing Creek, W. of Lorberry Creek, extends, with a slightly-curved course, obedient to the flexures of the South Mountain, to within 4 miles of the Susquehanna River. It is about 27 miles in length, has a breadth at its E. end of nearly a mile between Lorberry Creek and Fishing Creek; contracts gradually for several miles to half a mile between Rausch Gap and Yellow Spring Gap, and still further Westward,

tapers away to a very narrow belt, the bed of the valley steadily rising all the way until the Coal-measures terminate in a long and acute point, at a level of many hundred feet above the valleys outside of the bounding mountains. The basin is a simple compressed synclinal trough, the strata in the S. side dipping perpendicularly, while those in the N. side decline S. at an average angle of 45°.

UNDULATIONS OF THE STRATA IN THE SOUTHERN COAL-FIELD.

The researches of the Geological Survey, and the experience, often very dearly purchased, of the conductors of our anthracite mines, have at last induced a very general conviction of the necessity of attending to all the anticlinal and synclinal turns of the strata, for it is now admitted that these are the true key to the opening, tracing, and successful working of the coal-seams of the region. If a knowledge of them can be dispensed with, it is only where the operations are on the most local and limited scale. By showing the *lowest* known coal-beds which each given saddle or anticlinal axis lifts to the surface at every cross-ravine and other accessible point along its course, and again the *highest* seams which basin at the surface along each synclinal axis, a faithful description of any undulated district can be made to exhibit not only its structure but its *whole contents* below as well as above the water-levels. In this manner, by good geological maps and sections, we can show what coals are embraced in the saddles and what in the basins; and, moreover, at what heights and depths any particular bed may be reached. If the natural exposures of the strata, and the industrial developments connected with them, were such as to permit a perfect identification and tracing of every coal-seam, and a recognition of every wave or flexure, it would be possible, upon the plan I have adopted for the following detailed description of the coal-field, to represent, with almost the clearness of a model, the form and position underground of every sheet of mineral treasure it contains. But the materials for so thorough a picture do not exist, nor is it probable that they ever will at any one future epoch, since as fresh developments arise older ones are becoming obliterated, or the imperfectly-kept records of them are fading from memory. It is the more important, therefore, that I should define, with all the precision which the existing state of our knowledge allows, and in as systematic a manner as possible, every important undulation. A clear exhibition of these will prove of far greater consequence to the present and future industrial welfare of the district than any account of the existing mines or underground workings, however much of temporary interest this information may possess. The one condition of things is permanent and influential upon all mining operations; the other is transient, every few passing years replacing one state of the workings by others almost wholly different.

Classification and Brief Description of the Anticlinal Flexures or Saddles.—Before proceeding to a detailed description of the numerous anticlinal and synclinal flexures of this coal-field, it will be proper to define the axes of the first class systematically in the order of their distribution. Beginning at the E. end, this order requires us to treat the most Northern first, and to take them in succession Southward and Westward. This slight departure from our ordinary mode of procedure arises from the circumstance that the flexures are disposed in echelon from N.E. to S.W. It will be seen hereafter that the anticlinal and synclinal axes of the Mahanoy and Shamokin coal-field are also disposed in echelon, but in the contrary order, or from S.E. to

N.W.; while in the Northern, or Wyoming Basin, their disposition is from N.E. to S.W., as in the district before us.

In the following synoptic sketch, the successive anticlinal lines or flexures will, where it is possible, be designated by some geographical locality—a village or a colliery; and where greater precision is demanded by some well-known seam of coal arching or basining across them, as the case may be; they are also designated by letters for the sake of still greater precision, and are represented upon the Geological Map of the coal-field by the same. Still better to classify them, the leading anticlinals are designated by capital letters only, the lesser ones by small type.

The synclinal flexures or basins will be named from the anticlinal flexures which confine them; the marginal ones of the coal-field, by their bounding anticlinal and monoclinal belts. It is not intended that this outline-sketch of the primary and secondary flexures of the coal-field shall take the place of the more elaborate descriptions of both the anticlinals and their included troughs to be subsequently introduced, but it is given as a preliminary enumeration, in the belief that it will greatly assist both the practical and theoretical observer in comprehending the subsequent details.

ANTICLINALS FROM MAUCH CHUNK TO PATTERSON AND MINE HILL.

Anticlinal A, *Rhume Run and Panther Creek North Anticlinal.*—This is seen at the Rhume Run arch of coal, and in Panther Creek tunnels, Nos. 7 and 8. It extends from a point in the Sharp Mountain about one mile S.E. of Nesquehoning to a point nearly N. of tunnel No. 2 of the Lehigh Company's mines, or half a mile W. of tunnel No. 8, which cuts it. It curves gently Southward.

Basin A, or Anticlinal A *and Locust Mountain Basin.*—This most Eastern sub-basin of the coal-field, bounded on the N. by the Locust Mountain, and on the S. by anticlinal axis A, originating in the synclinal knob formed by the junction of Locust and Sharp mountains, deepens and widens Westward to the origin of axis A, and then follows the N. side of the valley at the base, and in the S. slope of Locust Mountain to the cessation of axis A. This basin is cut by the Mauch Chunk tunnel, by both of the Nesquehoning tunnels, and by tunnels 6, 7, and 8 of Panther Creek.

It is shown in the Section of the coal-field passing Summit Hill, Plate V. of Coal-sections.

Anticlinal a, *Panther Creek, South Anticlinal.*—This is the small anticlinal of the S. side of Upper Panther Creek, beginning near the head of Panther Creek, and expiring near Coaldale. Tunnel No. 9 intersects it a few hundred feet from the entrance. (See Section of the Coal-field at Summit Hill.)

Basin A a, or Upper Panther Creek Basin.—This is the sub-basin bounded by axis A on the N., and axis a on the S. The middle head-brook, and further W. the main stream of Panther Creek, flow centrally along it. Tunnels 8 and 9 begin in this basin. (See Section of Coal-field at Summit Hill.)

Anticlinal B, *or Summit Hill and Tamaqua Axis.*—This axis extends from Sharp Mountain E. of Mount Jefferson, through Summit Hill, and across the Little Schuylkill to near the mouth of Newkirk Tunnel. Near its intersection by Panther Creek the exposure of this axis is obscure, but there can be little doubt that it is continuous from Sharp Mountain to Newkirk Tunnel. Except near its E. and W. extremities, the flexure is much compressed. It is almost straight.

This flexure is well exposed at Summit Mines (see Section); also at Tamaqua (see Section).

Basin B, or Basin of Locust Mountain and Anticlinal B, *or Ashton and Tamaqua North Basin.*—Its E. end is bounded S. by Sharp Mountain to the beginning of anticlinal B, thence W. by that axis. Northward it is bounded by anticlinal A to Coaldale, thence somewhat further by anticlinal A, thence to Newkirk Tunnel by Locust Mountain. It thus extends, very obliquely, entirely across the coal-field. This synclinal trough is widest, and probably deepest, W. of the cessation of anticlinals A and A, or nearly opposite the middle of axis B. The Coal-measures in this basin are penetrated by tunnels 5, 4, 3, 9, and 2, and further W. by the Greenwood and Newkirk tunnels. (See the Sections.)

Anticlinal C, *Tamaqua Southern and Eastern Mine Hill Anticlinal.*—This axis is probably that which originates in Sharp Mountain at the head of Dry Hollow. It crosses Little Schuylkill through the S. edge of Tamaqua, passes S. of Buckville, S. of Tucker's Slope, and near the mouth of Palmer's Tunnel, and enters the E. knob of Mine Hill west of Big Creek. It then crosses Silver Creek S. of the narrow gorge in Mine Hill, and follows the N. side of the crest of its S. spur to the end, and is probably the arch to the S. of John's Slope on Mill Creek, W. of which it soon expires. The portion E of the Dry Hollow Ridge I propose to call C East, as the connection of this with the main flexure C is not yet fully established by continuous tracing.

Basin B C—Basin of Summit Mines and Dry Hollow Ridge, or of Anticlinals B *and* C *East.*—This is the basin of the Great Summit Mine. It heads E. obliquely on Sharp Mountain, embraces Dry Hollow and the most Southern branch of Panther Creek, and divides W. into *B b* and *C b* by the rising of the anticlinal B. Its N. side is reached by Tunnel 2 in Dry Hollow Ridge.

Anticlinal B, *Tamaqua Middle, and Newkirk Anticlinal Axis.*—This extends from Lower Panther Creek across the Little Schuylkill by the N. edge of Tamaqua to Newkirk Coal Breakers at Reinhardt's Run, beyond which it has not been traced for want of exposures, though it probably runs on for some distance W. For the features of this axis see Section at Tamaqua.

Basin b, or Basin of Greenwood Breaker.—This is the steep synclinal flexure between anticlinals B and B. It is the second, counting S., at the Little Schuylkill.

Basin C b, or Tamaqua and Newkirk Basin.—This is the third, counting S., at the Little Schuylkill. It is a S. branch of basin *B C*, and of basin *C*; Wabash Creek flows in it.

Basin C, or Anticlinal C, *and Locust Mountain Basin.*—This axis is limited on the N. as far W. as Newkirk by axis B, and further W. by Locust and Broad mountains. It is a wide capacious synclinal trough occupying between Newkirk and Tuscarora all the N. half of the coal-field. Westward, it is the Basin of Big Creek between Mine Hill and Broad Mountain. Centrally it contains the Buckville Tunnel, and also the Palmer Tunnel.

Anticlinal C, *Northern Tuscarora Saddle.*—This short axis proceeds from the N. base of Sharp Mountain opposite Buckville through the ridge S. of the Upper Wabash and Schuylkill watershed, and through the centre of Tuscarora village near which it ends. It is a narrow and comparatively unimportant flexure.

Basin C c, or Basin of Watershed, and of Carter's Tuscarora Slope.—This is the most Northern of the three sub-basins of the main Tuscarora Basin, or *C D.*

Anticlinal C C, *Tuscarora Church Saddle.*—This passes through the crest of the S. spur E. of the Valley Railroad, and through the S. Knob of Tuscarora Hill.

Basin c and c c, or Basin of the Centre of Tuscarora Village.—This is a short synclinal flexure of the strata under the village of Tuscarora.

ANTICLINALS FROM PATTERSON AND END OF MINE HILL OR BIG CREEK TO EAST NORWEGIAN CREEK.

Anticlinal D, *or S. Mine Hill Anticlinal.*—This is probably a continuation of the Tuscarora S. axis, undergoing a slight bend Northward between Big and Casca William creeks. It is not traced E. beyond Swift's Creek. This axis is seen in Whitfield Lower Tunnel; at the E. point of S. Mine Hill, and along the N. side of the crest of the same ridge to its Western end; and at Mill Creek, in the arch just S. of John's Breakers, or N. of Mill Creek Colliery.

Basin of C D, or Basin of Tuscarora and of Big Creek Colliery.—At Tuscarora it is probably undulated by the expiring axes C and C C. Further W. it is the basin of the collieries S. of the end of Mine Hill, of Whitfield's Upper Tunnel, and the basin of Casca William Creek between Mine Hill and the Sharp Ridge, called S. Mine Hill, and of John's Colliery on Mill Creek.

Basin D, or Basin of Sharp Mountain and Anticlinal C.—This is the fourth principal basin going W., which, heading in Sharp Mountain, deepens and widens Westward, and descends into the middle of the coal-field. It is the fourth or most Southern synclinal trough at the Little Schuylkill, and is that in which the S. mines at Tamaqua all lie. (See Tamaqua Section.) Opposite Buckville it becomes the basin *C D*, or that of Tuscarora, by the introduction of the anticlinal axis D at the base of the Sharp Mountain.

Anticlinal D, *Axis of Chadwick's Tuscarora Breaker, and of Brockville.*—It lies about 900 feet S. of axis D, and is seen at Chadwick's Mine, on the Schuylkill, S.W. of Tuscarora.

Basin D d.—A short narrow basin, one mile S.W. of Tuscarora, and N.E. of Brockville. It is but part of the small wave D, in the broader basin *D F*, or that of Patterson.

Anticlinal D D.—A short saddle crossing Bushy Valley, 1100 feet (?) S. of anticlinal D (?) or 80 feet (?) S. of Bushy Tunnel.

Basin D F, or Basin of Patterson between the Anticlinal Axes D *and* F.—This basin, commencing at the foot of Sharp Mountain, runs W., with one or two trivial saddles in it (D and D D), to Casca William Creek, where axis E subdivides it. Brockville and Patterson are in this basin.

Anticlinal E, *Casca William, Diamond, and Saint Clair Axis.*—This axis subdivides basin *D E* by rising W. of Bushy; it ranges N. of the S. Diamond Slope of Casca William, through the Big Diamond outcrop of Silver Creek, and through Windy Harbour. It swings the gangways in the Mammoth Vein, W. of Crow Hollow, and shows itself on Mill Creek in a flat undulation in the Primrose coal of Saint Clair.

Basin D E.—This is the basin of the Casca William White Ash Colliery, of the White Ash Collieries on Silver Creek and Zachariah's Run, of the Crow Hollow Mammoth Vein Colliery, and of the Mammoth Vein outcrops at Saint Clair. It is the N. and widest division of the Patterson Basin, and, ending Westward on Mine Hill, is a fifth instance of a synclinal trough running obliquely across the whole coal-field.

Basin E F, or Quigley's Hollow, Crow Hollow, and North Saint Clair Basin.—From Beachem's Mines, S.W. of Tuscarora to Bushy Valley, there is but one basin, that of D and F, the synclinal line of which ranges a little N. of Patterson. But from Casca William to Mill Creek, the axes E and F form a narrow basin, that of the Diamond Slope works on Silver Creek, and of the head of Crow Hollow, and of the Southern workings of the Mammoth Vein at Saint Clair. It ceases W. of Mill Creek, by the gradual dying-away of the anticlinal axis E.

Anticlinal F, *Patterson and Middle St Clair Axis.*—This axis ranges from Sharp Mountain near Beachem's Tunnel, passes S. of Patterson, arches the Adam Stahl Vein in Bushy Valley, and the lower vein on Casca William Creek, ranges through Quigley's Hollow to Silver Creek, crossing the Switchback road three times, passes Zachariah's Run S. of Windy Harbour, folds the strata at the N. end of the Ravensdale Tunnel, and crosses Mill Creek a little N. of Carey's Shaft, flattening on going W.

Basin F H and G H.—From Schuylkill Valley to Silver Creek the basin N. of axis H is limited by axis F. It crosses Bushy and Casca William creeks with one or two small flexures, the main synclinal axis being S. of the Adam Stahl Vein. From Silver Creek to Mill Creek it is the narrow basin limited on the N. by axis G, where it contains the outcrops of the Upper Diamond Coals. On Mill Creek this basin is that of the Big Diamond and Perpendicular veins. The E. end of this basin spreads S. to Sharp Mountain, on the flank of which it contains possibly one or two undulations.

Anticlinal G, *or Silver Creek Switchback, and Southern Saint Clair Axis.*—This axis, not visible on Casca William, crosses Silver Creek Valley through the S. brow of the hill of the Switchback Road, passes Zachariah's Run between its two close synclinals, Ravensdale near the Perpendicular Vein, and Mill Creek between the Diamond and Hancock veins.

Basin F G.—This basin, which passes through the Switchback Hill of Silver Creek, is that of the N. synclinal fold of Zachariah's Run, that of the Perpendicular Vein on Ravensdale, and that of the folded Hancock Vein in the W. side of Mill Creek.

Anticlinal H, *Sillimanville and Mill Creek Furnace Anticlinal.*—This seems to originate W. of Silliman's, and is the first main saddle N. of the junction of Bushy and Casca William Creeks, and first N. of the Old Furnace on Silver Creek. It crosses Ravensdale and Crow Hollow valleys S. of the Perpendicular Vein, and passes Mill Creek near Patterson's Furnace. It is the axis which bounds the long synclinal of the Peach Mountain coal on the N.

Anticlinal F.—In the N. spur which projects Westward from the N. flank of the Sharp Mountain S. of Patterson and Sillimanville, there are fallacious indications of an anticlinal axis in range with the S. dips of Milford Tunnel; but since its introduction on the Map, evidence has arisen showing that no true saddle exists there.

Basin f, ff.—This is the synclinal belt forming the hill S.E. of Sillimanville, penetrated by the Milford Tunnel. The synclinal axis coincides with the depression between the main crest and the subordinate S. ridge of the hill. This synclinal flexure is probably confined to the base of Sharp Mountain, as its N. dips are not seen W. of the Schuylkill. It belongs properly to the basin S. of axis I, but is not the main synclinal.

The coals embraced in this synclinal are the so-called Clarkson, Charley Pott, and Palmer, and one between the two latter. The Palmer has been mined round the E. end of its basin, from the tunnel back to it again.

Anticlinal F F.—This is an axis occupying the ravine S. of the air-shafts of the Milford Tunnel coals, and N. of the spur immediately E. of Middleport. Its N. dips are those of the basin of Milford Tunnel. No traces of this saddle have been detected at the Schuylkill.

Basin ff, fff.—The Middleport and New Philadelphia synclinal is evidently this basin prolonged into the spur E. of Middleport, and apparently into a recess between the two principal shoulders of Sharp Mountain, corresponding to saddles F F and F F F. The coal called at Middleport the Big Gate Vein, but erroneously so termed, is one of the North-dipping seams of the S. side of the basin.

Anticlinal F F F.—This is the most Southern of the small saddles of the Sharp Mountain group. It comes forth from a spur of the mountain about one mile E. of Middleport, and if prolonged so far, must cross the railroad at the village. E. of the village its position is in the ravine.

This anticlinal appears to be the N. boundary of Steinberger's basin, N. of the main spur of the Sharp Mountain, or Silver Hill, where the successive synclinal outcroppings of several coals have been found by shaftings directed by Dr Steinberger.

Basin of Axes F F F *and* F F F F.—Developed to some extent, as already mentioned, by shafting, this basin has its axis in the nook or recess between the first and second spurs of the mountain, where its coals must successively basin out to the E. This basin crosses through Calahan's and Preston's series of openings, and is probably that embraced between the Southern or middle anticlinals of the latter section.

Anticlinal F F F F, *or Silver Hill Anticlinal.*—This is the axis of the main spur of the Sharp Mountain, Silver Hill, S.E. of Middleport, and, assisted by the other shorter saddles just described, appears to have been the principal cause of the remarkable spreading-out of the Sharp Mountain on its N. flank in this region, as well as of the conspicuous deflection which its crest undergoes.

On this axis, between the W. end of the spur S. of Middleport, and its junction with the main ridge, some seven different coals have been opened, or partially mined. One of them has been penetrated by a tunnel by Mr Dobbin, reaching a coal from the S. side, which presently bends over the saddle, and in the curve of the gangway establishes the exact position of the axis.

As this axis rises rapidly Eastwards to where it lifts the conglomerate floor of the Coal-measures, and as the Sharp Mountain S. of it is not inverted, so as to give room in the basin between this and it for a thick succession of coals, we conclude that those which here arch the anticlinal are rather low in the series.

This axis is probably the most Southern exposed in the coal-openings of Calahan's section, N. of the so-called South-dipping Tunnel and Blackman's coal-seams. It appears to be that likewise which, at Preston's collieries, S.E. of New Philadelphia, arches the so-called Gate Vein.

It is probable that an intermediate saddle may lie between F F F and F F F F. The position of Steinberger's synclinal, so far S. from the saddle F F F, leaves some room for such an axis, and suggests the conjecture.

Upon the view we are inclined to take of the course of this axis Westward, it cannot be the true anticlinal of the Gate Ridge of Pottsville, but is one saddle, and possibly two, N. of that.

There seems to be a saddle in the N. crest of Bare Ridge, between Pinkerton's lower and upper tunnels, and one corresponding in range with it at Hevener's opening in Bare Ridge, E. of Cwmbola, and it is probable that this is the axis of the Main Sharp Mountain spur.

Basin of F F F F *and Sharp Mountain.*—Between the anticlinal F F F F and the monoclinal crest of Sharp Mountain, there is a regular high trough of the Coal-measures which we have thus designated. The Sharp Mountain strata of the S. side of this basin dip very steeply N., but are not overturned; those of the S. flank of the anticlinal spur are more gently inclined. The lower coals extend Eastward in this trough perhaps two-thirds of a mile beyond Dado's Tunnel, basining out with considerable regularity at a high level, but the extreme limit of the lowest seams has never been established.

This basin seems to be that of the South-dipping coals of Calahan's and Preston's southernmost developments, and is probably the synclinal of the N. side of Bare Ridge or Pinkerton's Upper Tunnel.

Dado's Tunnel in Sharp Mountain, cutting two coal-beds, intersects the steep N. dips of the S. side of this basin.

MAIN GROUP BETWEEN TUSCARORA AND MILL CREEK.

Anticlinal I—*Folded Anticlinal Flexure of Peach Mountain.*—South of the folded trough of the Peach Mountain coal, at a distance from it of from 400 to 600 feet, ranges a leading anticlinal axis, the first traces of which, towards the E., we detect in the hill S.W. of Milford Tunnel. It displays itself on Casca William, S. of the mouth of Bushy, on Lick Run near Murray's Mines, and on Silver Creek, disguised by close inversion in the hill just S. of the Old Valley Furnace. From Silver Creek we trace it to Zachariah's Run, which it crosses S. of the Silver Creek road, which is the position of the synclinal Peach Mountain Vein. We find it again in Ravensdale, in the hill near its mouth, and from Crow Hollow to East Norwegian it pursues the N. crest or shoulder of the double-topped hill S. of the Peach Mountain Basin. In all this distance this is the anticlinal of the Big and Little Tracy coals, and of those next immediately subjacent to them. It seems to have its maximum of elevation and compression in the district of Silver Creek, where it lifts out the fourth or fifth coal underneath the Peach Mountain bed. On Mill Creek and East Norwegian this axis becomes a subordinate roll on the N. flank of the there greater saddle I.

Basin of II and I, or Peach Mountain Basin.—This long continuous trough, commencing at the Schuylkill near Sillimanville, is traceable as far to the W. as the West-West Branch, and probably further. From Sillimanville to Ravensdale it is a simple synclinal, limited on the N. by the anticlinal H, and on the S. by the axis I, but from Ravensdale or Mill Creek westward, the axis I declines in prominence, and the flexure I increasing, this last maintains itself as far as the West Norwegian Valley as a true S. barrier of the trough, still undulated on its S. side by the enfeebled flexure I. Its N. border takes a change between E. and W. Norwegian by the declension of axis I.

The Main Peach Mountain coal follows the synclinal of this trough from Casca William to Crow Hollow, but near Mill Creek that bed has been swept off. But from East Norwegian W. to the West-West Branch or further, this coal retains its position there. In the district of Casca William, the trough is of the extreme normal structure ; that is to say, the N. dip is perpendicular, but from thence W. nearly to Ravensdale it is of inverted or folded type, both sides of the synclinal dipping S. On Mill Creek and East Norwegian the basin is less compressed, even the N. dip being comparatively gentle. On West Norwegian this grows steep again and irregular, and from this valley W. the S. side of the trough is throughout its chief length either perpendicular or overturned.

Anticlinal I.—This anticlinal has not yet been discovered as far E. as Zachariah's Run, but between this valley and Ravensdale, N. of Singley's Farm, we have it plainly indicated, and between Mill Creek and East Norwegian, and from the latter valley W. for a considerable distance, it is a conspicuous axis—the main S. border, in fact, of the there complex Peach Mountain Basin. Its function is to lift to the day the group of coals next beneath the two Tracy beds.

Basin I i.—From the proximity of the axes I and I, this synclinal belt between them is more frequently a flat undulation on the slope of the one or other of these anticlinals, than a regularly maintained basin or true trough.

Anticlinal J, *or Anticlinal at Cwmbola and Coaquenac.*—This axis has never been traced much E. of the valley of Cwmbola. It may be there recognised as a normal flexure with perpendicular N. dips, under which form it ranges on to Mill Creek, passing S. of Singley's farm. Crossing Mill Creek, it extends to the East and West Norwegian valleys, being inverted in structure everywhere from Mill Creek westward to West Norwegian.

On the East Norwegian it is the closely-folded inverting anticlinal of the coals N. of the outcrop of the Spohn Vein, and by its compressed oblique form and the irregularities of dip connected with it, it is one of the chief causes of the crushed and unsound condition of the coals along its range, as it traverses the Peach Mountain hills between the East and West Norwegian creeks.

Basin J i, or that of the Outcrop of the Lewis and Spohn Vein.—This is a N. division or branch of the main basin, N. of the Great Gate Ridge anticlinal. It occupies the high ground S. of the Peach Mountain coal, and is the obscure basin of the outcrop of the Spohn vein. As a distinct trough it is traceable only from Cwmbola to Middle Norwegian.

Basin J K, or general Basin N. of the Gate Ridge Anticlinal.—The wide belt between the long folded anticlinal flexure, I, of the Peach Mountain coal, and the still more extended and also folded anticlinal of the Gate Ridge, or K, which we shall call the Basin *J K*, is much complicated in its structure, especially towards its E. end, or between Middleport and Zachariah's Run, by the introduction of several lesser anticlinal waves subdividing it into a series of minor basins. The two most Eastern of these are F F and F F F, already indicated. Other three anticlinals occur in a group between the Schuylkill and the foot of Sharp Mountain opposite the mouth of Lick Run. They undulate the coal-seams wrought at Calahan's and Preston's collieries, and the reader will find what is known of their structure and contents in the sections illustrating those localities. Another anticlinal axis interrupts the symmetry of this wide basin S. of Cwmbola. It runs W. from Hevener's Drifts past the mouth of Pinkerton's Upper Tunnel in Bare Ridge, and seems to cease before reaching the Schuylkill.

Synclinal Axis.—The axis or deepest line of this basin is towards its E. end, the synclinal, which passes through Middleport, or *ff, fff* of Sharp Mountain; but W. of New Philadelphia the main depression of the basin appears to be a synclinal axis which ranges through Cwmbola and Belmont, and crosses Mill Creek south of the Sandrock coals, and follows the West Norwegian Valley, where it is parallel with the N. base of the Gate Ridge. This is evidently a very deep basin, containing as its uppermost coals the highest Red-Ash seams of the region.

Anticlinal K—*the Great Pottsville Anticlinal.*—This leading and conspicuous axis appears to originate to the Eastward on the Southern part of Bare Ridge, or probably at the base of Sharp Mountain, as far E., perhaps, as opposite Hubleyville or even New Philadelphia. It passes near Oliver's Bare Ridge Colliery, under the slope of the Selkirk Vein, at Chillis's new slope, and N. of Port Carbon, where it takes the S. side of the crest of the Gate Ridge; but it crosses the Norwegian above Pottsville through the N. brow of that ridge, which it follows thence sometimes along its crest, sometimes by denudation on one or other side, across the West Branch and the Swatara, and all the transverse valleys to the W. as far as the other side of Fishing Creek, where at last it coalesces with the Fourth Mountain, losing itself high on the Southern slope or even on the summit of this the N. barrier of the Dauphin Branch of the Pottsville Basin. From the passage of the Swatara to Lorberry Creek, this ridge, containing the Pottsville axis, bears the name of the Red Mountain.

This Gate anticlinal is the axis which forms the N. boundary of the S. or subordinate Sharp Mountain Basin. It is especially remarkable for its great length, and for its uniform direction from the point at which it first emerges from the Sharp Mountain, until it ceases to be traceable towards the W. Throughout a great part of this distance its course is marked by a bold continuous ridge, which, rising in height as it extends W., attains its mass and elevation in the neighbourhood of the Swatara, W. of which it again subsides. This ridge constitutes one of the most striking topographical features in the great Southern anthracite coal-field. It contains on its S. side the naturally South-dipping strata appertaining to the Pottsville Basin, and on its N. side the same either in a vertical position or pushed over into inverted S. dips. The vertical or inverted veins generally known as the Gate Beds, are evidently the same as the South-dipping coals of the S. side of the ridge folded over into N. or inverted dips.

Silver Hill Axis.—The place of origin of this anticlinal is possibly in the most Southerly of the spurs of the Sharp Mountain, which project forward towards the W. from that ridge in the region directly S. and S.E. of Middleport.

The Axis forming at first but an inconspicuous roll on the N. flank of the mountain, diverges from this ridge as it extends W., marking out the E. end of the Pottsville trough. As it ranges Westward it takes its course through the upper and lower Bare Ridges, where it intersects the Northern Tunnel. It does not reach the Schuylkill, but S. of Belmont, at the great bend of the road, the N. or vertical dips of the true Gate axis are well exposed. This extends through the hollow a little N. of Chillis's Slope, and further on becomes clearly marked in the topography by the lofty line of the Gate Ridge, which has been already traced.

On Mill Creek this Gate anticlinal may be seen on the E. side in the change of the dips, near the most Northern street of the village of Port Carbon, a little S. of the Engine Gate Vein. On the W. side of the valley it takes a position on the S. side of the crest of the ridge, and holds this relation to the summit the whole way to the Norwegian Valley at Pottsville, where it is indicated in the hollow or dimple in the end of the hill, there called Prospect Hill. On both of these valleys its precise relations to the topography and the coal-beds will be best learned from an inspection of the detailed Geological Sections of Mill Creek and the Norwegian.

Basin K, or that of the Pottsville Anticlinal and Sharp Mountain.—This extends from the S. base of Bare Ridge the whole way along the base of Sharp Mountain to the W. end of the Dauphin Basin. In the central part of its range it is deep, and contains apparently the thickest series of Coal-measures within the whole coal-field. The South Salem bed is its uppermost notable coal-seam.

Although it is not possible, in the present state of mining exploration, to trace the Gate Ridge axis E. of Bare Ridge, and unite it with that of Silver Hill, and therefore everywhere to define the N. boundary of the Sharp Mountain Basin, there can be no impropriety in considering them as at least connected, if not continuously, by a chain of short flexures lying very nearly in their prolongation. Indeed, the truest view to take of the Gate Ridge anticlinal, and of all the other great flexures generally, is that they are rather chains of closely-linked flexures a little out of line, and usually arranged in echelon, than that they are simple undulations continuous for very great lengths. Regarding then the Gate Ridge axis of Oliver's Mine in Bare Ridge as a part of the anticlinal belt of Silver Hill, we may consider the Sharp Mountain or Schuylkill Basin as beginning in the little cove between the crest of Sharp Mountain and Silver Hill, which is drained by Harriet Run, and which we have already entitled locally the Sharp Mountain Basin *ffff*. The lowest White-Ash coals, basining out to the E. in this elevated mountain-glen E. of Dado's Tunnel, range Westward along the N. slope of Sharp Mountain its entire length, to its termination near the Susquehanna. Throughout this S. border of the basin — which, as we have already stated, is also the S. limit of the whole coal-field—all the strata, from the conglomerates of the mountain-crest to the upper Red-Ash coals at its base, observe either a nearly perpendicular dip, or a somewhat inverted one. From the E. nook, which we will call Silver Glen, the strata in the Sharp Mountain, for a few miles W., retain a N. dip, growing gradually steeper until they become vertical; but beyond the neighbourhood of Port Carbon, where the mountain exhibits signs of a transverse dislocation, the rocks are slightly overthrown, and dip steeply to the S.; this inverted condition continues the whole way to Fishing Creek Gap in Dauphin County, beyond which the beds resume their nearly perpendicular posture, which they retain nearly to the termination of the Dauphin Basin, in the Big Flats where the dip rapidly flattens, and this long trough of the Coal-measures comes to an end. The upper or Red-Ash coals occupy the lower slope of the base of Sharp Mountain, the synclinal centre of the trough and the whole N. slope of the valley, to the axis or summit of the Gate Ridge or Red Mountain.

The synclinal axis of the basin is traceable from near the mouth of Dado's Tunnel, in Silver Glen, from point to point along the immediate base of Sharp Mountain. It is seen in the tunnel E. of Port Carbon, near its mouth, and in the bottom of the Salem Slope mines at Port Carbon and Salem Hollow, where it coincides very nearly with the average course of the Schuylkill River; again at Pottsville, just S. of the town, and in a similar position at the foot of the mountain at the West Branch Gap. We meet it again on the West-West Branch, S. of the E. and W. reach of that stream, between the gap and Silverton, and may detect indications of it along the same line still farther W. There can be little doubt, indeed, that this axis coincides with the lower slope or foot of the mountain S. of the Tremont Railroad, the entire distance to the Swatara, for we detect the strongest proofs of its presence, with an inversion of its S. side, where the Swatara turns Southward to pass through the mountain. We do not catch its precise position so accurately at the passes of Rausch and Lorberry creeks, but the inversion of the Sharp Mountain strata point very nearly to its place, as a glance at the sections will show. The N. side of this deep-folded basin contains a prodigious amount of very valuable accessible Red-Ash coal, though not a small proportion of the more superficial of these moderately-inclined South-dipping seams are in a greater or less squeezed and faulty condition, unfitting them for profitable mining. On the other hand, the Sharp Mountain veins, both Red and White Ash, are, from their perpendicular or inverted positions, so crushed and difficult to mine as rarely to reward exploration.

ANTICLINALS AND BASINS BETWEEN MILL CREEK AND WEST NORWEGIAN.

Anticlinal of Mount Laffy or E *West.*—An axis very nearly, if not exactly, in the line of the anticlinal E. of Mill Creek, is seen in the N. flexure in the Primrose Coal N. of Wadesville on East Norwegian, and extends thence as the N. flexure in the same coal near Mount Laffy, being the saddle of the Old Slope Mine at Brown's on West Norwegian. This flexure flattens Westward, and disappears about 400 yards from the West Norwegian, in Brown's Colliery.

Basin of C and E West, or Basin of Mount Laffy Tunnel.—The anticlinal axis D of Mill Creek, dying out in the flank of Mine Hill, between that stream and the head of East Norwegian, the basin at the S. foot of that ridge is bounded on the S. by the axis E, or its near equivalent in the Primrose Coal. I have therefore called this the basin *C* of the axis of Mine Hill, and E West.

Anticlinal F.—This flexure of the Primrose Vein, next N. of Carey's Shaft, appears to reach East Norwegian, where, however, it has the form of simply a flat undulation on the S. dip of the Primrose Coal N. of Wadesville. It is somewhat doubtful whether it reaches West Norwegian. A rather conspicuous flexure occurs there S. of Brown's Shaft, in the Primrose Coal; between E and C it is, however, not only steeper than the flexure F of East Norwegian, but it is further off from axis E, while we should expect it to be gentler if anything in its dips, and in about the same relative position.

Basin E F.—As both the flexures E and F are feeble undulations W. of Mill Creek, this basin cannot be defined beyond East Norwegian; even there these axes are at the water-level only low waves in the general S. dip of the Primrose bed.

Anticlinal G, *Axis of Big Diamond.*—The anticlinal axis G of Mill Creek, seen there as a closely-folded flexure S. of Carey's Shaft, is probably the more open flexure S. of Wadesville on East Norwegian, lifting to the day the coal next beneath the Big Diamond. In the same range, and probably identical with it, is a closely-folded flexure on West Norwegian, just N. of the Little Diamond coal, which it seems to invert into the Big Dirt-Bed. We see the same flexure in a corresponding position on the West Branch, and again on Wolf Creek S. of Spencer's Old Slope, N. of Minersville. It is there very near its termination, if our tracing of it be correct.

Basin F G.—This basin, already traced to Mill Creek, is that of Carey's Shaft, at the bottom of which, at a depth of 400 feet (?), it contains the White-ash Mammoth coal; the synclinal axis of the basin is in the Hancock bed, near the anticlinal G, its S. boundary. On East Norwegian it is the basin of Wadesville, where it contains the valuable Primrose Coal at no great depth beneath the surface. On West Norwegian it is the basin of the N. outcrop of the N. Diamond coal, and that of the first or S. outcrops of the Peach Orchard coals. From West Norwegian we follow it across West Branch and Wolf creeks, where it is the basin of the Big and Little Diamond outcrops.

Anticlinal H, *South Diamond Axis.*—The axis H of Mill Creek, or that which bounds the Peach Mountain Basin on the N., ranges thence as far at least as the East Norwegian, where it may be seen N. of McGinnes's boring, causing a steep N. dip in the S. Diamond coal. Whether it extends to West Norwegian is extremely doubtful, no N. dips there appearing in the line of its prolongation. We have thus traced this axis from E. of the Bushy Branch of Casca William, N. of Middleport, to the Peach Mountain N. of Pottsville.

Basin G H.—The anticlinal H not being traceable continuously to the West Norwegian, and another axis, N; or that of the Dripping Spring of the W. group, originating E. of the West Norwegian centrally in this belt, it cannot be defined as a regular basin W. of the East Norwegian. It there contains near its synclinal axis the Big Diamond and Perpendicular veins, as on Mill Creek—the Perpendicular having, however, a N. dip.

Anticlinal h, *Axis of McGinnes's Boring.*—Between Mill Creek and East Norwegian, or E. of the dying-out of axis H, there rises an anticlinal flexure a few hundred feet to the S., which extends without apparent interruption a very great distance Westward—as far, indeed, as the waters of the Swatara. It shows itself on East Norwegian as the saddle at McGinnes's boring; on West Norwegian as a flexure which doubles or inverts the Green Park coal some distance N. of the Delaware Company's Slope, and on West Branch as the axis next N. of Minersville, from which point to its W. termination its course will be presently defined under another head.

Basin H h.—On East Norwegian, where alone this flexure has any existence, it is a mere undulation on the N. slope of the saddle of McGinnes's shaft, or axis I. It appears to cease before reaching West Norwegian from the dying-out of axis H, and has no existence on Mill Creek, because the other axis h does not extend so far to the E. It results, in other words, simply from an overlap of the two anticlinals.

Anticlinal I, *Axis of Big Tracy Coal.*—This anticlinal, which has its E. end N. of Middleport, is, we have already seen, a very feeble flexure S. of the Peach Mountain Basin at Mill Creek. It is discernible on both sides of East Norwegian as a very flat subordinate wave in the Big Tracy coal on the N. slope of the anticlinal i, and faint traces of it are even seen below the Chenoweth coal on Middle Norwegian, but no vestige of it can be detected when we reach the West Norwegian Valley.

Basin h I, or Peach Mountain Basin.—The general course and structure of this basin have been already stated in tracing it to Mill Creek. The East and West Norwegian Sections will sufficiently display its form and contents where it crosses those valleys; it will be seen that, passing Mill Creek, it recovers the tendency to an inverted and faulty condition S. of its synclinal axis. Its uppermost useful coal is the Peach Mountain seam, the whole of the sounder portion of which, above the water-level, has long since been wrought out, and indeed the greater part of what remained in the South-dipping part of the basin at a lower level, down even to the synclinal axis. The S. side of this basin is here very irregular from the want of continuity, and the broken condition of the flexures I and i immediately bordering it. The whole basin will be more fully described in a later Chapter.

Anticlinal i, *or Peach Mountain Axis of Norwegian.*—From Ravensdale, where the anticlinal I begins rapidly to subside to the West Norwegian, this axis constitutes the true S. boundary of the Peach Mountain Basin. We see it on Mill Creek in the hill N. of Coaquenac, also on East Norwegian, arching the Big and Little Tracy coals of the mining village at the Pottsville and Minersville road. On Middle Norwegian it separates the South-dipping Clarkson from its North-dipping counterpart the Chenoweth, and on West Norwegian the N. and S. dips of the Spohn Vein. This axis has never been successfully followed Westward from the West Norwegian.

Basin i I.—This flexure on the S. side of the Peach Mountain Basin is too trivial both in breadth and depth from Mill Creek Westward to be regarded as a separate basin. As in the instance of the anticlinals H and h, it only exists where the anticlinals I and i lap past each other, or from a point a mile or so E. of Coaquenac to the Peach Mountain, W. of East Norwegian. Near this stream, and on both sides of Mill Creek Valley, the axis I is but a gentle wave on the N. flank of the anticlinal I. On West Norwegian, however, there intervenes between I and the synclinal line of the Peach Mountain Basin a flexure in the very line of I, which may be considered as its representative, and which presently, and for a great distance further W., puts on the same folded or inverted structure, and is the real South-bounding axis of the Peach Mountain Basin. It is the main anticlinal of Minersville, or axis O of the W. group, under which designation it will be presently traced out to its Western known limit. The uppermost coal undulated in this narrow shallow flexure is on Mill Creek and East Norwegian, the Big Tracy coal, or second below the Peach Mountain seam.

Anticlinal I, *Axis of Lewis and Spohn Coals.*—We have traced this anticlinal axis from its E. origin N. of Cwmbola to its position on Mill Creek, S. of Singley's farm. Like several of the others above enumerated, it ranges across East Norwegian, but is not recognisable at the West Norwegian Valley. On the East Norwegian it is well exposed as a sharp compressed flexure with inversion of its N. side, folding the South-dipping Mason coal back under itself as the South-dipping Clarkson. We discover proofs of its presence at the Middle Norwegian mines, or North American Company's, in the North-dipping or Perpendicular coal which occurs between the Lewis and Spohn veins, and proves them to be one and the same bed. From its retaining so steep a N. dip, it is not probable that this flexure actually ceases E. of the West Norwegian, but that it exists disguised as a South-sloping fault.

Basin i J.—This is the Spohn vein on Little Norwegian; but as we are unable to trace the anticlinal axis J further W. than Little Norwegian, it cannot of course be recognised in a separate basin even at or W. of the West Norwegian Valley. Its identification with one of the basins S. of Minersville will depend upon the continuity of the axis I, and into what W. flexure it may run.

Anticlinal K, *the Gate Ridge Axis.*—This remarkably long and straight flexure extends through the present division of the coal-field from Mill Creek along the N. brow of the Gate Ridge to the Norwegian Valley, which it passes a little N. of Pottsville. On both streams it inverts the same group of coals, and lifts to the day the self-same bed, the *Lion* or *Barn coal*, as our Sections show.

Basin J K, or Norwegian Basin.—In the district under description the basin *J K* ranges from Mill Creek to West Norwegian as a very regular broad and deep trough, its S. side dipping perpendicularly, and its N. side, without subordinate undulations, at a moderate inclination Southward to its synclinal axis. This central line of the trough ranges just N. of Pottsville, and precisely in the bed of the valley of the E. and W. reach of the East Norwegian. The highest coals here contained in it are near Mill Creek, the Salem group of Pottsville, and on Norwegian the Sand-rock beds next lower in the series.

The great continuous anticlinal flexure of the Gate Ridge, and the basin between it and the Sharp Mountain, of a length still more prolonged, having been already sketched for their entire extent, and our description of the lesser ones N. of them being now brought as far W. at least as the West Norwegian, it is proper we should enter now upon the description of the Western System of axes with which some of those already sketched are continuous. To these we therefore proceed.

WESTERN SERIES OF FLEXURES.

As nearly all the flexures of the strata W. of the meridian of Pottsville either originate in the country to the W. of the coal-field, and expire before they reach the Norwegian, or lie exclusively in the W. half of the basin, it will be expedient, for convenience of classification, to treat all these undulations as a series separate from the E. ones already described. With the exception of the remarkably continuous anticlinal of the Gate Ridge and Red Mountain, and the still more persistent one of Mine Hill, none of the W. set of waves are traceable E. to the West Norwegian; and it has been already shown that all the E. anticlinals, if we except the doubtful instance of the axis G, or that of Saint Clair, die away or become very obscure before reaching the West Branch. It is nevertheless probable that some of the saddles, especially the more folded ones of the disturbed country between the Mill Creek and West Branch valleys, do actually extend through and connect both systems, making the basins between them continuous; for it should be remarked, that what we often call separate axes are but the same lines of flexure shifted sidewise, a lateral plication of a wave becoming its principal crest: indeed, an extensive anticlinal belt not unfrequently shifts thus its crest-line many times in succession, either in a given direction, in echelon, or in a zigzag manner. I conceive that some such condition prevails to no small extent in the Peach Mountain Basin, or the much-disturbed central zone of the coal-field embraced between H H, &c. on the N., and I I, &c. on the S., and extending from the Schuylkill, N.E. of Middleport, W. as far at least as the Swatara.

The better to aid the reader's apprehension of the intricacies in the structure of the central and W. divisions of the coal-field, I shall pursue the mode adopted for the E. series of designating them by letters, and, as before, by well-known localities used as convenient synonymes. It will develop their relations more clearly to trace them from W. to E., as all the more conspicuous ones sink away in this direction. We shall advance, as formerly, from the N. toward the S. side of the basin.

ANTICLINALS.

Anticlinal L, *or Woodside Anticlinal.*—This is the most Northern flexure of the W. division of the basin S. of Mine Hill. Whether it originates on Broad Mountain W. of the Swatara, or still further W. in the Red Shale Valley of Pine Creek, has not been ascertained, but it is one of the flexures which serve to spread the Seral conglomerate in very flat undulations over the S.W. plateau of the mountain. The axis-line crosses the Swatara about three-fourths of a mile N. of Swatara Falls, and ranges thence E. to the S. base of Mine Hill near Woodside, crossing the head of the West-West Branch 1000 feet N. of the tunnel. It is here a flat roll in the Black Valley coal and the stratum next under it. How much further E. it may extend we have not definitely ascertained; it probably soon ceases altogether.

Anticlinal M.—This anticlinal, hitherto discerned only on Middle Creek, crosses that stream N. of the Swatara Falls axis, at the passage of the road to Sherman's, about four-fifths of a mile or 4200 feet N. of the axis of the Dripping Arch. Its course takes it towards the centre of the basin N. of Swatara Falls, but whether it reaches the Swatara is uncertain.

Anticlinal M, *or Axis of Swatara Falls.*—One of the most extensive and interesting saddles of the W. series is that which ranges along the spur of the Mine Hill or Broad Mountain, which is crossed by the Swatara at its falls. This axis seems to originate in the Umbral red shale, and to cross Middle Creek in a wide but very gentle flexure in the conglomerate and lowest Coal-measures. Dipping very slowly E., and passing the Swatara Falls, it is first saddled by the lower coal-beds between the Swatara and Muddy Creek, and, still declining, is successively overarched by higher and higher strata, passing the York Tunnel, Patten's Valley, and Primrose Hill, to its termination E. of Wolf Creek, on the E. side of which it is discernible on the Minersville road. Between Patten's Valley and Wolf Creek the anticlinal part of this flexure is distinctly double, as will be shown more fully hereafter.

Anticlinal L, *or* F *West.*—Between the head of Patten's Valley and the West Norwegian ranges an anticlinal which in strictness does not belong to the W. series, but is one of the very moderately long flexures confined to the middle portion of the coal-field. On Wolf Creek it is the saddle of the Oak Hill coal or Little Peach Orchard, and on West Norwegian, the Mount Laffy axis, or that which arches the Primrose coal S. of Brown's Shaft. This anticlinal lies too far S. by several hundred feet to be in the line of axis F of Mill Creek and East Norwegian; indeed, its course would take it just N. of Wadesville. I have nevertheless called it F West, as there is a possibility that the two actually coalesce somewhere between the East and West Norwegian valleys. Its better designation, however, will be L, or the Oak Hill axis.

Basin L M.—The basin N. of the Swatara Falls axis commences W. somewhere in the vicinity of Middle Creek, but precisely how far W. the lower Coal-measures run has not been ascertained. From the Swatara E., the basin deepens somewhat rapidly, and as its S. anticinal, or that of the Falls, itself also declines in the same direction, it is obvious that it soon contains a thick body of Coal-measures. Thus Morgan's Tunnel, which lies nearly in its centre, goes on some distance N. before it cuts the first large White-Ash coal. York Tunnel lies also in this basin, but on its S. side. As we approach the valley of West-West Branch, the S. dips of the N. side of the basin becoming very gentle, and the N. dips of the S. side very steep, the synclinal axis of the basin lies more and more S. in it, until it passes through Patten's Valley, to range closer and closer to the anticlinal of Primrose Hill, until it reaches Wolf Creek, where the Swatara Falls or Primrose axis expiring, and the now more prominent undulation G, of the middle series, situated a little further S., now becoming the S. boundary of the basin, it ranges on somewhat more centrally in the trough, here that of F West, and G, until in turn the axis F West is no longer discernible E. of the West Norwegian. I am not aware that the W. limit of the Red-Ash coals within this basin has been yet discovered, but it is probably E. of the head of Muddy Branch. The section illustrating what is known of the coals of the West-West Branch will explain at a glance the positions which the several beds there occupy in this basin, as also its form; and the West Branch and Wolf Creek section will make its whole structure and contents for that district equally intelligible. A comparison of these two serves to show how rapidly it subsides towards the E., with the introduction of higher and higher coals, until it receives even a slender trough of the Kantnor Peach Mountain itself.

Anticlinal N, *or Axis of the Dripping Arch and Phœnix Mines.*—About 1800 or 2000 feet S. of the anticlinal axis M, there ranges another of even greater length, and of unusual straightness, from the Southern flank of Broad Mountain N. of Donaldson, the whole way apparently to the West Norwegian. Its W. origin is obscure, but it is distinctly developed on Middle

Creek, in the beautiful arch of conglomerate at the Dripping Spring, from whence I have chosen one of its names. Forming the S. boundary of Fisher's Basin, it ranges from the Dripping Arch, and crosses the Swatara at M^cCreary's Mines N. of Tuckerville. It passes Muddy Branch at the Hecksher New Mines N. of Dewartsville, and at the West-West Branch is the flexure of the Phœnix North-slope Mine ; at least, I am disposed to identify these two anticlinals. From the Phœnix Mines it ranges across Wolf Creek, as the saddle which divides the Peach Mountain coal from the Kantnor, and it appears to reach and cross the West Norwegian Valley, as a closely-compressed fold near the Big Diamond coal. Like the others, this anticlinal wave evidently sinks steadily Eastward. For the portion of the coal-field W. of the West-West Branch, it is the true N. boundary of the Peach Mountain coal-seam, though Eastward of that valley this valuable Red-Ash bed, under the name of the Kantnor Vein, not only spans it, but the axis M still N. of it.

Basin M N, or Fisher's and Kantnor Peach Mountain Basin.—The W. origin of this basin is on the S. slope of the Thick Mountain west of Middle Creek, a mile or more N.E. of Donaldson. Properly the trough has no definite W. end, but is a branch of the Donaldson Basin, gradually forking from it by the rise of the anticlinal axis of the Dripping Arch. On Middle Creek and Swatara it is known as Fisher's Basin, where, and until it approaches the cross valley of Muddy Branch, it contains only the lower or White-Ash coal-seams. On the West-West Branch, where, by the declension Eastward of both its bounding anticlinals, and their increased steepness of curvature, the basin is much deeper, though somewhat narrower, it receives, as our Section shows, a progressively increasing thickness of the upper Red-Ash coals, first the Big Diamond bed, and finally in Primrose Hill, midway between the West-West Branch and Wolf Creek, the uppermost thick one of them all, the Kantnor or Peach Mountain coal. Passing Wolf Creek, this basin narrows, and changes its N. boundary by the cessation of the anticlinal of Primrose Hill, and the introduction of the somewhat more southern axis G west. Under these new relations, as the narrow trough *G N* it ranges past West Branch to West Norwegian, where, as our Section there will show, it contains at the water-level the Little and Big Diamond and adjoining coals. The axis N not reaching the East Norwegian, this belt, as a special basin, ceases W. of that stream.

Anticlinal O, Minersville South Axis, or Flexure South of the Peach Mountain Basin.—An interesting flexure, or chain of nearly continuous flexures, somewhat difficult to trace, may be followed Westward from the Peach Mountain past the S. edge of Minersville, and across West-West Branch S. of the Phœnix Colliery, and the Muddy Branch near Weaver's, the whole distance to the East Branch of Swatara Creek. It is most probably an almost continuous axis from the neighbourhood of Wagner's Tunnel to the E. fork of Swatara. In its position as respects the compressed South-dipping and faulty basin, or oblique synclinal fold of the Peach Mountain seam, it represents the flexure I of Mill Creek, and the country E., and may be looked upon, indeed, as a second clear development of the same compressed wave, locally obscure between the East and West Norwegian valleys, either from the dying-out of the axis I, or from the W. portion O degenerating into a fault. Indeed, the dips which are met with on West Norwegian, S. of the synclinal axis of the Peach Mountain coal, strongly imply the prolongation of axis O eastward to this valley, as if to take up the line of the anticlinal I of East Norwegian. Some doubt exists as to the strict continuity of this anticlinal axis between the Southern edge of Minersville and the axis arching the Peach Mountain coal on the West-West Branch, some persons imagining the latter to be a prolongation of the saddle just N. of Lewis's Old Tunnel west of Minersville ; but the course of the Peach Mountain gangways, and the range of the two axes, seem to settle the question despite the intervention of a great dislocation intercepting the course of the N. flexure.

Basin N O, or West Peach Mountain Basin.—Somewhere to the E. of Donaldson, and probably to the W. of Swatara, the wide and deep basin in which that town lies between the anticlinals N and Q, forking Eastward by the introduction of the flexure O, there commences an independent basin, embraced between *N* and *O*. This basin begins to deepen rapidly after passing the Swatara, and by the time it reaches Muddy Branch, it includes almost the highest of the Red-Ash series of coals—in the opinion of many, the Peach Mountain bed itself, though this is somewhat doubtful, as cannot but appear when we reflect that 2 miles further E., or at the valley of the West-West Branch, the bottom of the Big Diamond coal, the third seam below the Peach Mountain, is only a little below the water-level, while the Peach Mountain bed itself runs out of its West Branch basin E. of the West-West Valley in the hills S. of the Phœnix Mines. It should be observed, moreover, that the basin nowhere rises Eastward from Muddy Branch until we approach the short and narrow anticlinal o, of Minersville; for while its North-bounding axis N sinks progressively to Wolf Creek, and even to West Norwegian, its South-limiting flexure grows more and more compressed and folded in the same direction, and thereby deepens the synclinal depression of the trough. The Geological Map and the Sections explanatory of the structure of this basin on West-West Branch, and West Branch, will sufficiently indicate the contents and shape of this interesting central basin of the coal-field.

Anticlinal O, *or Minersville Axis.*—A short anticlinal axis extends under the N. part of the town of Minersville, and just N. of Lewis's Old Tunnel. It forms locally the N. boundary of the much-compressed, obliquely-dipping, or folded synclinal basin of the Peach Mountain coal; the other, or Minersville south axis, constituting its S. limit by inverting the strata on its N. flank into S. dips. The short axis o brings up the coal-seams which next underlie the Peach Mountain Vein, near the mouth of Lewis's Tunnel.

Anticlinal P, *or Griscom Anticlinal Axis.*—S. of the Minersville S. line of flexure, at a distance of from 1600 to 2000 feet, there ranges an anticlinal axis, or, more probably, a chain of several nearly continuous saddles, for a distance of many miles. I have given that axis of the belt which extends between West-West Branch and West Branch the name of the Griscom axis, from its passing through an estate of that name lying N. of Llewellyn. It has not been traced far to the E. of the West Branch, unless indeed we regard the anticlinal axis I of the West Norwegian as identical with it—a view which appears by no means improbable, when we reflect that the faulty condition of the strata S. of that flexure on West Norwegian, in the Lewis Vein, may be connected with a break in the line of the axis, jogging the W. portion towards the S. Taking it up where it crosses the West Branch S. of Minersville, we may trace it through the Griscom lands, under sundry irregularities, and a considerable deflection in its course to the West-West Branch, and we may carry it thence along the hills, though somewhat obscurely, to the Muddy Branch, and so on to the East Branch of Swatara, a few hundred feet N. of its mouth, and to a cutting in the Swatara Railroad, half a mile N.W. of the Pottsville and Tremont Turnpike. To avoid a positive identification of the portion W. of Muddy Branch with the part E. of it, I prefer to call the former P West. I believe it has not been detected W. of the Swatara.

Anticlinal P, *or Swamp Axis of West-West Branch.*—There is a small anticlinal flexure visible to the E. of the West-West Branch, about midway between the last-described anticlinal P, and the S. Minersville flexure O. It is not detected on the West Branch S. of Minersville, and a swamp hides it in the valley of the West-West Branch, beyond which, in the absence of mining, we have not been able to find it.

Axis P P.—Another small anticlinal, possibly continuous with P, crosses the Muddy Branch about 1200 feet S. of Martin Weaver's residence; its course E. and W. is but imperfectly known. As the continuity of the Griscom axis of West-West Branch with P West of Muddy Creek and Swatara is not established by accurate tracing, it is possible that P P is the true W. prolongation of the first-named flexure, in which case P West, if it have an E. prolongation, would be continuous with the flexure Q Q N. of Minersville, the course of which across West Branch carries it only some 400 feet S. of axis J, or that of the Lewis and Spohn Vein of East and Middle Norwegian.

Basin O P, or that N. of the Main Griscom Saddle.—As we have no clear exposures of either of the anticlinal axes O or P West in the Donaldson Basin to the W. of Swatara, but only indications in the features of the ground of their extension in that direction, it is expedient to regard this basin as a middle prong or subdivision of the wide one between the Thick Mountain or axis of the Dripping Arch and the anticlinal of the Big Lick Mountain south of Donaldson. This basin, or rather this somewhat irregular synclinal belt, may be traced with little interruption, if we regard the Norwegian axis I as a prolongation of the Griscom axis P the whole way to Mill Creek. It evidently contains an extensive outcrop of the Peach Mountain coal-seam on the upper main bed of basin *N O*, known by that designation. It is apparent, however, that neither this nor any of the other uppermost Red-Ash Coals run in an unbroken manner through the length of this somewhat irregular trough; for not only does its South-bounding main axis P West, P and I, shift its position and alter its degree of flexure, but there rise within it several lesser saddles, of which P P and P are examples, each of which deflects the outcrops of its coals, and alters the course and continuity of its main synclinal line on the bottom of the basin.

Anticlinal Q Q, *or Llewellyn North Axis.*—This anticlinal, being, as just stated, nearly in line with axis J of the E. series, may prove to be continuous with it; and this supposition is the more conceivable that the axis J belongs to a flexure both wide and steep at the North America mines on Middle Norwegian, where we last behold it. The absence of any connecting evidence on West Norwegian does not overthrow so natural an hypothesis, since there is a ground notoriously blank and obscure some distance S. of the Lewis Vein through which axis J may pass undiscovered. The actual course of Q Q would seem to take it, however, too far S., or among the small Sand-rock coals of the West Norwegian.

Axis Q, *or Anticlinal of the Big Lick Mountain.*—This flexure originates Westward as a roll on the N. slope of the South-bounding mountain of the Wiconisco Basin opposite Klinger's Gap. It ranges thence through the crest of the Big Lick Mountain, saddled first by the conglomerate, and then further E. by Coal-measures, and, passing S. of Donaldson, crosses Good Spring Creek, Coal Run, and Middle Creek, and reaches the Swatara Railroad, where its arch is well exposed in a cut a few hundred feet N. of the turnpike. The flexure is here neither broad nor steep, and would seem to be near its E. termination. Though the feeble anticlinal Q seen on West-West Branch opposite the centre of the village of Llewellyn is almost precisely in a line with the axis of this flexure Q, I hesitate to regard and name them as the same, from the absence of any

N. dips in a wide space of country between them. The axis q appears, moreover, to ascend Eastward, and not Westward, as it should, if identical with Q.

Axis q, *or Middle Llewellyn Axis.*—As just intimated, this small flexure, faint at the West-West Branch, grows more conspicuous E. It is seen on the West Branch a little N. of the railroad bridge, in a gentle arch of sandstone, with a long succession of S. dips between it and the folded synclinal trough of the N. base of the Gate Ridge. This flexure would not appear to reach the West Norwegian. It remains for future mining developments in the district between the Muddy Branch and the Swatara to prove whether or not it is the Big Lick axis sinking very slowly down.

Basin of P, Q q.—The Western portion of this synclinal belt, or that embraced between *P* West and *Q*, may be regarded as the S. or third prong of the wide synclinal valley of Donaldson: it is not distinctly discernible on Muddy Creek, but there is a basin (that of *P* and *q*) N. of Llewellyn, into which it appears to prolong itself, unless, indeed, it is the N. half of that basin, or the trough contained between the Griscom axis P and the middle axis Q q; in either case it extends Eastward to the dividing ground or watershed between West Branch and West Norwegian; and if Q q be identical with J, it is prolonged much further.

Anticlinal R, *or Axis of the Little Lick Mountain.*—This conspicuous and extensive anticlinal axis enters the coal region from the Red-shale district of Williams' Valley through the head of the Kettle, and ranges along the crest of the Little Lick Mountain to Tremont, a little E. of which it crosses Good Spring and Middle creeks, trending into the N. base of the Red Mountain until it becomes apparently a component flexure of that ridge, assisting to give it the breadth and elevation it exhibits W. of the passage of the Swatara. It is to be seen in that gorge within a few hundred feet N. of the main axis of the ridge, well exposed in the cuttings of the Swatara Railroad (see Section). E. of this locality no traces of it have been detected. This Little Lick anticlinal, of which I shall speak more in detail in another place, is peculiar among the W. series of flexures in running somewhat obliquely to their prevailing course, and in subsiding much more rapidly than they do to the Eastward. It belongs, as it were, to a different system of undulations—is, in fact, simply the E. termination of one of the grand primary crust-flexures of the country beyond the Susquehanna—the flexure of the Half-Fall Mountain, or more truly of Amberson's and Path valleys; whereas the others which adjoin it in the coal-field are to be looked upon as secondary or more superficial corrugations, belonging, not to the whole depth of the earth's once flexible crust, but only to the higher strata, plicated in part, at least, by the lateral pressure due to the concave bending which formed the wide and deep trough of the Southern coal-field.

Axis r.—This is a small anticlinal axis visible on the Swatara Railroad several hundred feet to the N. of the axis R of Little Lick Mountain.

Axis r r.—This is a flexure seen on Muddy Branch, a mile or more W. of Llewellyn, and about 1000 feet S. of the Turnpike.

Axis r r r.—An anticlinal axis lying about 1200 feet N. of the main axis of the Red Ridge, ranges along the lower reach of Muddy Branch, and thence across the West-West Branch near the second railroad bridge, one-fourth of a mile S. of Llewellyn. It probably ranges still further Eastward in the N. flank of the Gate or Red Ridge, and may be one cause of the serious disturbance of the Coal-measures of that anticlinal belt.

Anticlinal S *or* K, *or Axis of Red Mountain and Gate Ridge.*—Enough has been already stated concerning the course of this remarkably straight and persistent anticlinal flexure to identify it at its various points of intersection by the streams of the country, and I shall reserve for another chapter what details I have to offer respecting its local effects upon the strata which saddle it.

Basin Q R, or that of the Big and Little Lick Anticlinals.—This synclinal trough has its W. origin in the high valley between the Little Lick and Big Lick anticlinals, at a point several miles W. of Tremont on the N. slope of the Lick Mountain; it widens and deepens Westward, and, approaching Good Spring Creek, receives the Red-Ash Coal-measures, still expanding and deepening by the recession of its South-bounding saddle R; it merges into the broader, more persistent basin *Q S*, or *Q K*, of the N. side of Red Mountain and Gate Ridge. As the middle and E. sections of this wide synclinal belt have been already sufficiently sketched, any further notice of it will be postponed to the chapter of details.

Basin R S, or that of Tremont.—This synclinal flexure, contained between the Little Lick axis on its N. and the Red Mountain anticlinal on its S., unlike the above-described basin *Q R*, contracts rapidly towards the E., though from Rausch Creek to Swatara it evidently contains its full complement of coal-seams: its rapid diminution of breadth is due to a converging of the anticlinals which confine it, both of which curve convexly as they approach. The contents and structure of this basin at the three transverse valleys of Swatara, Rausch Creek, and Lorberry, where its coal-beds have been somewhat carefully opened, are clearly shown in our Sections of those several ravines. As will be observed, it contains at Tremont not fewer than twelve distinct beds of coal above the water-level, all of which belong to the Upper or Red-Ash series. At Rausch Creek, the main bed of coarse conglomerate at the bottom of the Coal-measures is uplifted above the water-level to a high elevation in the axis of Little Lick Mountain; and S. of this, about 2000 feet, the Big White-Ash coal of the W. end of the coal-field has its outcrop, with a gentle S. dip. It again nearly reaches the water-level in the anticlinal axis of Red Mountain; thus the lowest Red-Ash coals extend Westward from Tremont in successive superposed basins to the brow of the plateau looking down into the ravine of Rausch Creek.

Axis s, *or Anticlinal of Silvertown Colliery.*—This is the most Southern flexure hitherto detected in the W. division of the basin. It has not been traced beyond the locality whence it takes its name. Its relations to the main folded anticlinal S are well exhibited in the Section illustrating the West-West Branch.

CHAPTER II.

FIRST OR NESQUEHONING AND PANTHER CREEK DIVISION OF THE DISTRICT BETWEEN THE LEHIGH AND TUSCARORA.

In the detailed description of the Coal-measures of the Southern Basin, upon which we now enter, the numerous natural belts, anticlinal and synclinal, will be treated in the order observed in the sketch of the anticlinal axes presented in the preceding Chapter. Not only will the axis-lines of the flexures—that is to say, the tops of the saddles and the bottoms of the basins—be traced with all the exactness which the information collected will permit, but the individual coal-seams will be treated of, their positions and relations to the saddles and basins pointed out, their outcrops followed where this is practicable, and their order of superposition, distances from each other, and respective thicknesses carefully made known. As a detailed written account of every measured section of the coal strata, printed in this work, would make the text unnecessarily voluminous, and as all the information that could be thus set forth in writing is embodied in a clear and condensed shape in the accompanying engraved Sections and Diagrams, possessing a suggestive power which words cannot aspire to,—as all the elements of the composition and structure of the Coal-measures are there displayed even to the nicest features in the curvatures of the strata, their degrees of dip or slope, the measured intervals which divide the coals, and the subdivisions of the coal-seams themselves,—it is highly expedient that the reader should constantly consult the appropriate drawings while perusing the text. He is also earnestly recommended to resort frequently to the Geological Map, to acquire, in connection with the Sections, clear conceptions of the districts under description, and of the precise positions of the localities referred to.

The great extent and complexity of feature of the coal-field, make it expedient to consider it under subdivisions, even though the limits of these are somewhat arbitrary. I have already shown that it admits, upon a large scale, of a division into five somewhat natural districts; and I shall proceed, in the first place, to review the structure and contents of the most Eastern of these, or that which extends from the point of the basin near the Lehigh to the head-waters of the Schuylkill, where it loses its slender and simpler structure, and begins suddenly to expand and grow complex. In connection with the tracing of the undulations, and of the groups of coal-beds lifted and depressed by them, numerous details, especially of the more permanent class, will be presented concerning the conditions under which the coals occur at all the more important mining localities where they are now wrought, or have been opened. Much description of the interior workings of the mines, collected in the progress of the Survey merely as data towards the identification and mapping of the saddles and basins, and the tracing of special coal-veins, will be omitted, inasmuch as such statistics are constantly changing, and are, moreover, of an interest too purely local to justify a permanent record.

EASTERN END OF THE COAL-FIELD, ESTATES OF THE LEHIGH AND LITTLE SCHUYLKILL COAL COMPANIES.

Beginning of the Coal Strata.—The general form of the E. division of the basin, or that which lies between the Lehigh and Tuscarora, is, as we have seen, that of an acutely-tapering synclinal trough. It terminates, as all similar basins do when enclosed by ridges of any of the harder rocks, in a high prow or elongated oval summit, formed by the union of the two mountain monoclinal barriers of the basin. In the instance before us, the knob in which the coal-basin commences is not absolutely symmetrical as respects the general synclinal line of the trough, but is situated almost wholly to the N. of it. It is, in fact, the prolongation of the crest of the Northern or Locust Mountain, that of the Southern or Sharp Mountain being here broken down. Thus, while the massive conglomerate beds of the Locust Ridge extend into this terminating summit, those of the Sharp Mountain outcrop lower down on the steep S. slope, only the higher ones appearing above the level of the Back Track Railroad. This feature is the result of a want of symmetry in the dips of the outcrops of the conglomerate, that of the Sharp Mountain being almost vertical, and everywhere much steeper than that of the Locust Ridge.

Eastward from this highest knob of the basin, and almost exactly in the *synclinal axis*, there is a partially-detached lower summit called Mount Pisgah, inferior in height to the loftier one by perhaps 100 feet, and separated from it by a narrow neck or *col*, depressed 60 or 70 feet below the level of Mount Pisgah. This last-named hill is formed of the lower member of the conglomerate formation, while the neck which joins it to the main mountain is excavated in the softer sandstones composing the central group. Mount Pisgah is therefore the extreme E. point of the Seral conglomerate, the very lowest layers of which may be seen, near their contact with the superior beds of the Umbral red shale, about one-third of the way down from the summit Eastward, exposed in the cuttings for the inclined plane which rests on this slope of the mountain.

From what has just been said of the positions of the two bounding ranges of the conglomerate, it is obvious that the end of the included Coal-measures is not in the terminating knob, but on the S. slope of it. Here, in fact, the point of the basin has been obliquely shaved away on its S., or rather S.E. side, so that it does not end by the closing round it of the conglomerate, but is nipped abruptly off with the destruction of its S. barrier. This greatly-denuded point of the trough of the coal-rocks may be traced from the spot where some coal has been opened in it, just W. of the little reservoir, Eastward above the level of the railroad for several hundred yards, to where all signs of the Coal-measures vanish, on the S. flank of the high knob.

Westward from the reservoir, the waters of which are manifestly supplied from the drainage of the coal-rocks overlying the conglomerate, the S. border of the basin becomes better supported by the rising of the Sharp Mountain barrier of conglomerate. First the upper or N. rib of this formation assumes its proper place on the margin of the basin, in the form of a narrow craggy ledge of very steeply North-dipping strata. This ledge becomes conspicuous at about two-fifths of a mile W. from the reservoir, from which point W. the basin, ceasing to be obliquely truncated, loses its irregular character of a mere denuded terrace, subordinate to the S. slope of Locust Mountain, and takes its natural position between barriers of nearly equal elevation on its two borders. At the distance of nearly half a mile further, the lower or S. rib of the Sharp Mountain conglomerate likewise gains in due succession its proper elevation, and from this point forward forms the outer crest and brow of the ridge, which, thus strengthened and augmented, assumes and maintains an elevation equal to that of the crest of Locust Mountain. The Sharp Mountain rocks throughout their whole range, from E. of the little reservoir to the meridian of Nesquehoning, present an almost perpendicular dip, seldom inclining less than 85° N. Those of the Locust Mountain, from the terminating knob of the basin to Nesquehoning Notch, and indeed for a far greater distance, dip S. at an angle which seldom exceeds 60°, for the upper or S. strata, and by the curving of the whole mass is as low in many places as 45° and even 30°, on the N. or lower layers. Towards the E. end of the basin, in the vicinity of the little reservoir, the dip on this strike appears to be at its maximum, the whole synclinal trough lying here evidently closely folded. It is to the greater steepness of the Sharp Mountain strata, compared with those of Locust Mountain, that we must ascribe the greater denudation or cutting-down of the former ridge by the waters which once rushed over the basin from the N. The depression at the reservoir, which separates the knob from the main crest of Locust Mountain to the W., is likewise the result of the same Southward-moving current.

The E. end of the basin, embracing the Coal-measures from the reservoir W. for nearly one-third of a mile, is not at all basin-shaped or trough-like in its profile, but is simply an elevated flat, bounded by the Locust Mountain and Sharp Mountain ledges of craggy conglomerate, which rise above its plane not more than 40 or 50 feet. But from the point just specified, the surface included between these barriers takes a hollow form, and soon assumes the curve of the point of a beautifully-modelled spoon. As we advance half a mile or so further W., where the two borders of the trough become more nearly straight, diverging but slowly from each other, the whole valley tapers in the form of a gradually-expanding shallow boat, with low but steep bulwarks, and the bottom sloping gently on both sides toward the keel. Such is its contour in the vicinity of the Mauch Chunk Tunnel, and for 1½ miles W.

From the point now reached the basin assumes new features. The Locust Mountain or N. barrier, holding its rectilinear course to the Kitchen Gap at Nesquehoning, becomes steeper on its S. flank, and by a stronger denudation more terraced. The central deeper bed of the valley containing the Kitchen Creek is now more profoundly excavated, and approaching the meridian of the sudden elbow of the stream where this leads Northward, it is sharply ravined, the whole surface presenting here the cross section of the bottom of a great ship, furnished with a very deep keel.

Anticlinal Axis A, or Rhume Run Anticlinal.—About the point where these features begin, or nearly 1½ miles W. of the Old Tunnel, the Sharp Mountain assumes a significant feature, bulging in a broad knob, and bending somewhat more Southward in its trend to the W. This point appears to mark the commencement within the basin of an anticlinal flexure of the strata, which extends hence to the N. side of Panther Creek, and is not lost until we reach the meridian of Dry Hollow, on a position yet further W. The influence of this saddle in the rocks, which I shall call the Rhume Run Anticlinal, is a very important one upon both the topographic features of the basin and the distribution of its coal-beds. It divides the general coal-field between the Sharp and Locust mountains into two subordinate basins, the Northern being the prolongation of the single Eastern one, which we may name the Mount Pisgah and Hell-Kitchen Basin, while the Southern is that which contains the main waters of Panther Creek, the name of which I propose for convenience to apply to it. This latter has for its S. boundary the crest of Sharp Mountain, and the anticlinal spur into which this prolongs itself at Summit Hill, and as far W. as Dry Hollow. The Northern or Kitchen Run Basin is deeply intersected transversely by the ravines of both the Kitchen Run and Rhume Run, which discharge their drainage through their respective notches in Locust Mountain, near Nesquehoning. The S. subordinate basin, originating, as was indicated, about a mile E. of the position of Nesquehoning, has here a high table-land surface, which extends W. as an elevated skirt from the base of the crest of Sharp Mountain, all the way to the S. head-ravines of Panther Creek — its only obvious indentation being a ravine opening N.E., which contains the S. prong of Rhume Run. Between the ravines of Rhume Run and those of the sources of Panther Creek, the whole general basin, including the central anticlinal and the two synclinals, is filled up to one even level contour, presenting large breasts of coal in the two subordinate troughs.

Course of the Rhume Run Anticlinal traced.—This well-marked anticlinal axis defines itself very beautifully at sundry points along its course. We first encounter it going Westward, in the long Nesquehoning Tunnel (No. 1), where it causes the steep N. dip of the N. vertical seams, and other coal-beds next S. of this. Traced to the ravine of Rhume Run, the very axis itself is seen exposed in a grand saddle of coal, long ago laid open to view, at what is called the Fifty-feet Vein, the coal-bed being here that which elsewhere in this locality is known as the Twenty-eight-feet Seam, the actual thickness of which is, however, generally 14 or 15 feet. (See the Plate, which presents a view of this fine saddle of coal as it was to be seen in 1840, when the mine was actively wrought.) At a lower level than this arch, the two dips of the twenty-eight feet coal are seen in the Rhume Run Tunnel, or that called No. 2 of the Nesquehoning Mines. On the W. side of Rhume Run the axis is well expressed in a jutting hill or knob, which rises here immediately in the line of the great arch of coal. Following the course of the anticlinal through the table-land or watershed of the valley, it is first indicated in the wide gentle central ridge which starts from Rhume Run in the hill just mentioned, but at the very watershed it is scarcely marked at all upon the surface. From this high flat, Westward, it may be very distinctly traced in the crest of the long symmetrical ridge which this plateau sends forward between the ravines of the Middle and N. branches of Panther Creek. The exact place of the axis is revealed at the extremity of this spur, where the strata, crossing the stream, are exposed between the mouth of Tunnel No. 6 and the Coal-Breaker connected with the mines here. Its position is about 400 feet S. of the tunnel. The axis is again exposed nearly a mile from this point in Tunnel No. 7, close by its mouth, and is distinctly and for the last time revealed in Tunnel No. 8, about another mile still further onward. From this point forward we may see in the form of the surface the prolongation of this straight and regular anticlinal for yet a mile or more Westward, beyond which it is at present too vaguely indicated to be traceable. That this anticlinal does not reach the Little Schuylkill, nor even the ravine of the Greenwood Tunnel, will be quite obvious to the reader upon his merely inspecting the sections at those places. The undulation evidently smooths itself out at the foot of the Locust Mountain, somewhere opposite the point of the long spur of Summit Hill, a mile or more Westward from Coaldale.

A, *Panther Creek S. Anticlinal, or Subordinate Axis of Panther Creek.*—I must here observe that we have indications, both in the topography and the dips of the strata at a few points, that there exists a second parallel and smaller anticlinal a thousand feet or more to the S. of the main one already traced. It appears to start from the high flat ground S. of Rhume Run Gap, and pass through the Southernmost ravine of Rhume Run, thence through the watershed and the spur which this sends off between the Southern and middle forks of Panther Creek, and thence along the brow of the ridge which bounds the immediate valley of Panther Creek on the S., as far as the base of the Panther Creek inclined plane No. 2. Thus the main stream of Panther Creek would seem, in the part of its course opposite Summit Hill, to flow along a central small synclinal trough midway between the two approximate anticlinals.

This axis is intersected in Tunnel No. 9 about 300 feet S. of its entrance, where it exposes excessively steep dips, and is partly compressed. The anticlinal here coincides very nearly with the summit of the ridge, the height of which about Panther Creek approaches 100 feet. (See Section of the Coal-field from Sharp to Locust mountains through Summit Hill, Plate VI.)

B, *Summit Hill and Tamaqua Anticlinal.*—The next great feature, structural and topographical, which we encounter in our progress Westward along the coal-field, is the broad and well-marked

Anticlinal of the Summit Hill.—I have already defined this to be approximately but not strictly in the prolongation of the great anticlinal of Mine Hill, which here, at the Summit Hill, passes out of the basin through its S. barrier of conglomerate. The axis of this bold flexure is first developed to the Eastward in the high expanded summit of Sharp Mountain, which is called Mount Jefferson, where the dips on both sides of the axis in the arch of the Seral conglomerate on the crest of the mountain are extremely gentle. The whole mountain at this broadest point embraces indeed not only the anticlinal arch, but the extreme end of the basin of the E. Mine included between this anticlinal and the crest of Sharp Mountain. In its course Westward this anticlinal holds up the conglomerate in a gradually-contracting mountain-spur for a distance of $1\frac{1}{2}$ miles as far as the W. edge of the village of Summit Hill, past which spot, a little W. of the crossing-point of the main public road, the axis is overarched by the Coal-measures, the Great Surface Mine, or open quarry of coal of the Lehigh Company, here commencing. From this place the ridge-line of the flexure is traceable through the old mine, with everywhere a dip of 40° or 45° on its S. side, and a steep one of 75° or 80° on its N., to where the two grand outcrops of the gigantic coal-bed unite, and saddle the axis about 1000 feet W. of the mouth of the Slope mine called No. 2. The precise position of the axis is under the N. edge of the village of Summit Hill, again about 100 feet S. of the Catholic chapel, and again almost exactly at the Breaker House of the Great Slope Mine. From this last-named spot the anticlinal and the spur which it sustains point downward in their W. course, until the axis crosses the ravine called Dry Hollow. Its course thence is high on the N. slope, and along the crest of the Dry Hollow spur or ridge, within which it is intersected by the Dry Hollow Tunnel at a point about 700 feet in or Southward from the mouth. From the W. part of this high ridge, which, for a certain distance, almost coalesces with the N. flank of Sharp Mountain, the further course of the anticlinal for half a mile is a little vague, but we recover traces of it immediately on crossing Panther Creek south of the ravine of Greenwood Colliery, where the axis passes between the public road and the Coal-Breaker. Thence to its exposure at the Little Schuylkill its position may be approximately made out by its topographical indications, in the absence of definite exposures. On both sides of the river I have detected the exact place of the axis within a possible error of a very few yards.

It will be observed, on inspecting our Section of the basin at the Little Schuylkill, that three anticlinals are indicated. The existence of all of these is obvious from the directions of the dip in the rocks. The S. one is the Mine Hill axis, and the N. one the prolongation of that of the Summit Hill or Sharp Mountain anticlinal. As, however, the interval at the river between the Northern and Middle one is only 650 feet, and that between the Middle and Southern does not exceed 850 feet, all three may be regarded as but undulations in one main anticlinal ; and our view will not err either in its practical bearings or its theoretical soundness, if we consider the Mine Hill and Summit Hill flexures as essentially one continuous line of uplift.

The Mine Hill axis, in its E. extension crossing the Little Schuylkill on the S. edge of the village of Tamaqua, seems to be prolonged Eastward from the river for a short distance at least, but how far, it has been impossible to ascertain. This axis is evidently already very faint at Tamaqua, as the section there will show, and it is possible that it does not pass the river more than a mile or so before it ceases altogether ; yet there are indications that it reaches the Sharp Mountain S. of the Great Summit Mine.

SYNCLINAL BELTS OR BASINS.

Having traced with sufficient minuteness the anticlinal flexures of the E. end of the coal-field as far W. as the Little Schuylkill, let us, before proceeding further, describe the subordinate basins which they enclose, and the Coal-measures which lie within them.

Basin A, or Synclinal Trough of Anticlinal A *and Locust Mountain.*—This Easternmost subdivision of the coal-field, bounded on the N. by the Locust Mountain, and on the S. by the anticlinal axis A, originates, as we have seen, on the S. slope of the terminal mountain-knob of the coal-field, near the little reservoir above the railroad. It deepens and widens Westward between Locust and Sharp mountains, to the place of the commencement of the anticlinal axis A, on the shoulder of the last-named ridge, beyond which it follows the N. side of the valley, at the base, and in the S. slope of Locust Mountain to the cessation of axis A, where the trough merges into the wider basin *B*, contained between the Locust Mountain and the anticlinal axis B of Summit Hill, prolonged thence to Newkirk. Throughout its entire length, indeed to the Little Schuylkill, and still further, the Coal-measures of the N. side of this straight and regular trough have a rather uniform undisturbed dip S. of from 45° to 60°. They ascend in many places nearly to the top of the S. slope of the Locust Mountain. Some of the lower coal-beds, especially the Great Summit stratum, being very thick, their lines of outcrop are distinctly expressed in many places by slight, nearly level indentations along the flank of the mountain, looking, under the slanting Western sun, like ancient half-effaced beaches, or long-neglected roadways. These benches on the mountain, as they are called, are particularly distinct opposite Summit Hill. A sketch here introduced (see Plate) illustrates well their features in that part of the basin, when beheld late in the afternoon of a summer's day, or, better still, when the snows of winter cover all the lesser inequalities of the surface and all confusing diversities of colour, and display only the softer contours of the surface.

From the E. head of the basin for nearly 2 miles W. to a bulge in the Sharp Mountain, which marks the commencement or passage of the first anticlinal axis, the Coal-measures of the S. side of the trough possess a nearly vertical dip, like that of the conglomerate of the mountain. This E. end of the basin, though not traversed by any yet known anticlinal axis, shows a considerable amount of disturbance, especially towards its centre, as might be inferred from the excessive steepness of the strata, and their confining walls of conglomerate. The Lehigh Company's Old Mauch Chunk Tunnel, as it is called—the first ever constructed in the coal region—lies nearly one mile W. of the point of the basin. It perforates the entire thickness of the conglomerate of the Sharp Mountain, and apparently reaches the Big coal of the basin, the position of which is nowhere far above the conglomerate, with seldom more than two comparatively thin coals between them. The large coal, however, is in a thoroughly squeezed and jumbled condition, and wholly unfit for mining. It is evident, indeed, that it occupies merely the synclinal axis of the basin, and that the central depression of the trough contains not a simple synclinal curve, but a succession of close and confused foldings of the superficial strata—an almost invariable feature towards the ends of those coal-basins which exhibit a sharp or steep flexure of the rocks.

Indeed, it is not conceivable that the soft Coal-measures, the uppermost formation, should be otherwise than greatly crushed or plicated, compressed as they must have been at the steep uptilting of the far less yielding formations which underlie them. It is not probable, therefore, that this extreme E. division of the coal-field, the end of basin *A*, will afford much coal in a sound enough condition for working; there is, however, a fair prospect of a good body of tolerably sound coal W. of the tunnel, towards the Hell-Kitchen Gap at the S. base of the Locust Mountain, where the dips do not exceed 60°. Near the line of the tunnel, the Lehigh Company caused a deep cross-trench to be cut not far from the synclinal axis of the basin, but the coal—probably the large bed of the Nesquehoning mines called Twenty-eight Feet Bed, but actually measuring 15 feet—proved to be in a thoroughly crushed condition. Another cross cut, some 400 feet W. of the line of the former, also shows an apparently large mass of squeezed coal; and a third lesser one, 300 feet S. of this, was made with no better success. A coal 10 feet thick at the outcrop was opened near the line of the tunnel, on the S. edge of the very crest of the Locust Mountain.

NESQUEHONING MINES.

These mines are part of the coal estate of the Lehigh Company, and are situated about 4 miles W. of the E. point of the basin opposite the mining village of Nesquehoning. The Locust Mountain—sometimes erroneously called the Nesquehoning Mountain—is here cleft by two deep notches; the more Eastern of these, called the Hell-Kitchen Gap, from the excessive ruggedness of the ground, discharges the Kitchen Run, which drains all the E. end of the basin. The more Western, half a mile distant, is called the Rhume Run Gap, discharging a stream of that name which heads W. and S. a mile or more distant against the sources of Panther Creek.

The Coal-measures of the basin *A* we are describing are deeply cut and well exposed in the ravine of Rhume Run, and have been for many years extensively mined for their coal, and I propose to show, with the aid of a Section, as far as the developments and the data collected will permit me, the particular type which the Coal-measures here put on. As the Section speaks for itself, showing the horizontal distances between the outcrops of the principal coal-beds, their angles of dip, and their horizontal thicknesses, a detailed description of it will not be necessary.

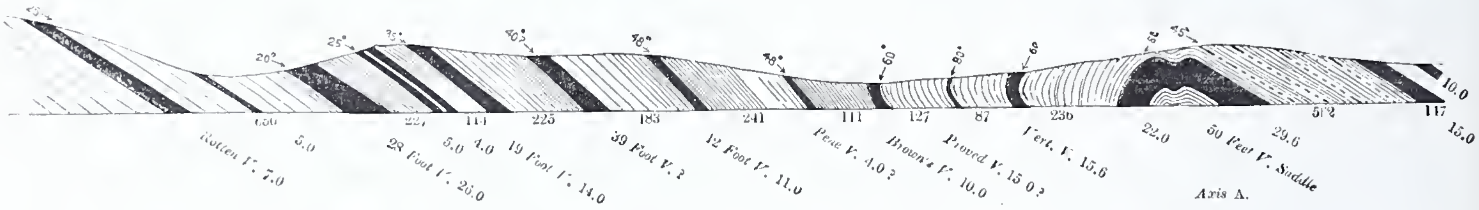


FIG. 138.—Section of the Coal Strata at Rhume Run, looking E.

The measurements were made in 1840, when many of the developments were less obscure than, from dilapidation of the older workings, they are at present; but it should be observed that some additional facts have probably since come to light, of a nature to modify slightly the results here presented. The precise position of the synclinal fold has not, I believe, been ascertained, but it is probably somewhere between the 12-feet coal dipping S., and the apparently inverted coal called the Pencil Vein. We revised the ground in 1852, and found some new developments, requiring us to modify our previously carefully-gathered notes.

Two long tunnels have been cut across the strata, intersecting in all nineteen strikes of coal, but some of them under three repetitions, from the circumstance that they cross the anticlinal axis A from the N. basin to the S. one next the Sharp Mountain. These tunnels cut seven separate coal-seams, of diameters from 3 to 17 feet; which, when originally opened at their outcrops, appeared to be far thicker, and some of them are still designated by their first-imputed exaggerated sizes. Nevertheless their dimensions at this locality are unusually large, the amount of coal in the first few hundred feet of the Coal-measures rivalling that to be found anywhere in the general coal-field. Besides the seven workable beds here enumerated, the outcrops of two or three others have been opened, showing thicknesses of 2 feet and less

The following tables, politely furnished by the officers of the Lehigh Company in 1853, contain the most authentic data procurable, respecting the thicknesses and workable capacities of the several seams. Their distances asunder are not given, but these are approximately presented in the engraved section, constructed from our earlier measurements.

COALS IN TUNNELS Nos. I. AND II., NESQUEHONING MINES.

TUNNEL No. I.

No.	Name.	Horizontal Thickness.	Thickness at right angles.	Estimated working Coal.	Observations.
1	Rotten vein				
2	...	...	3 feet		
3	28-feet vein	22 feet	14½ ,,	say 9 feet	Identical with No. 13.
4	5 ,, ,,	...	4 ,,	,, 4 ,,	,, ,, 11 or 12.
5	19 ,, ,,	29 ,,	17 ,,	,, 8 ,,	,, ,, 10.
6	39 ,, ,,	26 ,,	15 ,,	,, 8 ,,	,, ,, 9.
7	12 ,, ,,	16 ,,	12 ,,	...	,, ,, 8.
8	Pencil vein	14 ,,	...	...	,, ,, 7.
9	Brown ,,	14 ,,	...	...	,, ,, 6.
10	N. vertical vein	18 ,,	16 ,,	,, 8 ,,	,, ,, 5.
11	6-feet vein	6 ,,	...	...	
12	4 ,, ,,	4 ,,	...	,, 3 ,,	
13	50 feet N. dip	25 ,,	...		
14	50 feet S. dip	31 ,,	...		
15	3-feet vein	4 ,,	...		
16	10 ,, ,,	18 ,,	...		
17	26 ,, ,,	26 at bottom of tunnel.	average 13 feet.		
18	14 ,, ,,	14 ,,	...		
19	11 ,, ,,	11 ,,	...		

TUNNEL No. II.

10	N. vertical				
11	2½-feet vein	...	2½ feet		
12	2½ ,, ,,	...	2½ ,,		
13	50 feet N. dip	27 feet	23 ,,	say 9 feet	
14	50 feet S. dip	38 ,,	30 ,,		
15	2-feet vein	...	2 ,,		
16	1½ ,, ,,	...	1½ ,,		
17	S. vertical	12 ,,	...		
18	A new vein.	...	5 ,,	,, 2½ ,,	

Comparing the data presented in the first Table with the engraved Section, it will be observed that the latter exhibits a thin coal, called the Proved Vein, between Brown's Vein and the North

Vertical, whereas no such appears in the list of those cut in the tunnel. On the other hand, two coals—the 6-feet and the 4-feet seams—occur in the tunnel between the North Vertical and the great arching coal called the Fifty Feet. Our Section, however, shows these on the S. side of the great saddle, and in their right position above the so-called Twenty-eight Feet Vein, of which the saddle is but the anticlinal uplift; there is therefore no discrepancy except in the introduction of the thin coal between the North Vertical and Brown's.

How far along the basin to the Eastward each of the seven main coals, intersected by No. 1 Tunnel, extends before it is finally lifted out in a point by the continuous rising of the whole trough, it is impossible, in the absence of extensive mining and shafting in that direction, to ascertain, but it is pretty obvious that the uppermost can hardly pass the ravine of the Kitchen Run: the underlying seams must, however, extend in broad and regular breasts between the centre of the valley and Locust Mountain a good distance E. of the ravine; the lowest of the large ones—the so-called Twenty-eight Feet Vein, or third in the ascending order—reaching to the Mauch Chunk Tunnel, but much crushed towards its E. termination, as we have already seen. It is a point of interest to know how far this large coal, No. 3, continues to span the anticlinal axis Eastward from the tunnel. It is exposed, as we know, in the ravine of Rhume Run, where it exhibits the remarkable saddle represented in the sketch (see Plate); and as our Table shows, it is cut in both the tunnels. The rise of the axis most probably brings it to the day somewhere opposite the turn of the Kitchen Run towards the N. It is not probable that either this or any of the overlying coals will be found to contain on their N. dip, either along the anticlinal axis or the Sharp Mountain eastward of Rhume Run, any considerable amount of sound merchantable coal.

The coal-seams of the Nesquehoning mines are for the most part wrought by "drifts" or "levels" leading E. and W. from the tunnels following the course of the beds. Some drifts are also carried in from the water-level of the ravine, and the Big Seam has also been mined by a slope or an inclined plane, with railway-tracks laid on the slanting floor of the coal-bed, and with a stationary steam-engine as the lifting power, after the manner prevalent in the coal region. From the mouths of the drifts the coal is conveyed by short branch-roads to a central or trunk railroad Northward across the strata towards the opening of the notch in the mountain, where a long inclined plane, descending at an angle of 6°, overcomes the declivity of the ravine, and conveys the coal to another railroad at the village of Nesquehoning, by which it is transported to the Lehigh Navigation at Mauch Chunk, a distance of about five miles.

Though we cannot determine strictly the position of the synclinal axis of the basin, the evidence preponderates for placing it just N. of the Pencil Vein. Upon this interpretation of the Section, the Third or Twenty-eight Feet Vein, so-called, and the so-called Fifty-Feet Vein, are but different outcrops of one and the same bed. This is manifest from their agreement in thickness. Upon the same hypothesis, the Fifth or Nineteen-feet Vein by name, actually 17 feet thick, has its other outcrop in the N. vertical vein; and the Sixth or so-called Thirty-nine-feet Vein, the real thickness of which has been ascertained in the tunnel to exceed 15 feet, is the equivalent of the Brown Vein; while the Twelve-feet Vein and the Pencil Vein are the two outcrops of the uppermost, separated by the synclinal axis or fold. Upon this view, the counterpart of the double bed, sometimes called Rowland's Vein, which next overlies the third or main South-dipping coal, is the fourth or 5-feet seam near the mouth of the tunnel.

COAL-SEAMS OF THE NESQUEHONING MINES.

I proceed now to give a description of the several coal-beds.

No. 1. *Rotten Coal.*—This is apparently the lowest coal in the series, though its distance above the assumed top of the Seral conglomerate has not been definitely ascertained. Its total thickness is about 7 feet, of which 5½ feet are coal. This coal burns well enough, but is crumbly and unsaleable. It resembles much, both in its aspect and fracture, the corresponding lowest bed of the Tamaqua mines. Where mined, the roof or top slate has not been firm, but shaly, though the floor or bottom slate was strong and hard. This was mined chiefly on the W. side of the ravine, where there were two drifts, one on a level with the railroad, and the other about 60 feet above it. But this mine is now no longer prosecuted. The slope of the hill on the E. of the ravine is such as to give it too little breast there to make the mining of it profitable, even if the coal had proved of a quality suitable for the market. Its dip is 25° S., and its strike is nearly E. and W.

No. 2. *Two Thin Coals.*—Between the Rotten Coal and the Main Lower Coal, two thin seams are known, but their distances from it are not accurately ascertained. One showed at the outcrop about 15 inches thickness of crushed coal; the other was also very narrow, but its real dimensions had not, at the date of our first observations, been recorded by the miners. Subsequently one of them has been mined near Tunnel No. 1, and, according to the table, measures 3 feet.

No. 3. The *Main Lower Coal*, called the Twenty-eight-feet Vein, has its outcrop 650 feet to the S. of the Rotten Coal, and is separated from it by an actual thickness of 222 feet of coarse sandstone and slate. The total width of this bed, measured horizontally, including its benches of slate, is about 22 feet, though, from the disturbances in the dip, it is somewhat variable. It consists of several portions :—

1.	Upon the bottom slate rests a layer of slaty coal dirt, ...	1 foot.
2.	To this succeeds the lower bench of coal, usually 7 feet, but occasionally 13 feet thick, .	7 feet.
3.	Next a slate of variable size, increasing, as the drift advanced W. of the mouth of the mine, to	4 „
4.	Above this a layer of bone-coal, or slaty coal, ...	5 „
5.	And capping the whole, an upper bench of coal, never more than	5 „
		22 „

The actual thickness is 14½ feet in the tunnel, and the amount of marketable coal is, on an average, 9 feet.

The original mine was on the W. side of the ravine. The bed was entered by three drifts in all, with a difference of level of 40 feet between each two. Only the lower one was persevered in. In one of the upper ones, the top and middle slates cut out all the coal. When first entered, the bed preserves for 100 yards an average thickness of 25 feet, having a few seams of slate, but yielding a very good coal. At about that distance a fault or curl in the top slate was encountered for a short distance, and beyond it the coal has never been as firm and regular as previously. The middle slate, which now divides the bed into two benches, was originally but a few inches thick; but passing the fault, it swelled to the dimensions already stated. At the termination of 700 yards the drift ends in 6 feet of coal. The disturbances in this mine were generally in the top slate.

As with nearly all the beds at this locality, the dip is not constant. At the mouth of the drift it is 20° S., but further in it increases, and occasionally is perpendicular ; at 260 yards in it is 50° S., and at 700 yards 40° S.

No. 4. *Rowland's Coal,* or the double bed, outcrops 227 feet to the S. of the Main Coal, being divided from it by 77 feet of rock. This bed consists of two seams of coal separated by 3 or 4 feet of slate. The lower bench of coal was opened on both the E. and W. sides of the ravine, and measured 4 feet of very inferior coal, and was therefore never followed ; but the upper coal, which was likewise entered in both directions, yielded on the E. side, where it was soundest, about 5 feet of good coal with no slate. In the tunnel it contains 4 feet of good coal. On the W. side it was more disturbed, there being a succession of rolls for the first 150 or 200 feet, beyond which the bed was regular, with a dip of 25° S. ; whereas near the entrance of the drift the dip is 60° S.

It was stated to us by the intelligent superintendent of the mines, that a little to the S. of the lower bench of this double bed, he met with the largest bed of *iron ore* seen in these mines. Time had obliterated the freshness of the excavations, and we were therefore unable to ascertain either its amount or quality.

No. 5. The *Nineteen-feet Coal,* the real thickness of which in the tunnel is 17 feet, has its outcrop about 114 feet to the S. of the Double Vein, with an actual thickness of intervening strata of nearly 57 feet. Where this bed was opened on the E. side of the ravine, it consisted, beginning with the bottom, of, 1st, about 2 feet inferior coal ; 2d, 6 inches of slate ; 3d, 4 feet of coal ; 4th, a few inches of slate ; 5th, from 2 to 3 feet of coal ; and 6th, the remainder of the bed, soft or dirty coal. On the W. side of the ravine the bed was opened at a higher level ; but here a roll, or rather a small anticlinal bulge of the whole bed, occurs, upon both sides of which rather good coal was obtained : but all mining upon this coal was subsequently abandoned. This bed is not very regular in its course or dip. The average dip is 35° S.

No. 6. The so-called *Thirty-nine-feet Coal,* the true thickness of which is about 15 feet, is distant from the last-described bed 228 feet, and overlies it by 137 feet of interposed slate and sandstone. On the W. side the bed exhibits an anticlinal dip in the drift, with the coal 10 feet thick on each side of the axis. Extending the drift along the Northern or steepest leg of the arch, the dip suddenly changes from 35° or 40° N. almost to perpendicular. Believing that the coal must rise again, the superintendent of the mines caused a tunnel to be driven Northward through the top slate, and thereby reached, at no great distance, a steep South-dipping bed of coal, 23 feet in thickness, much of which was of good quality.

The two following diagrams, one a section of the bed at this point, and the other a ground-

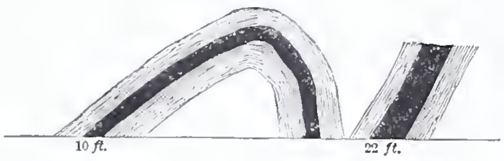
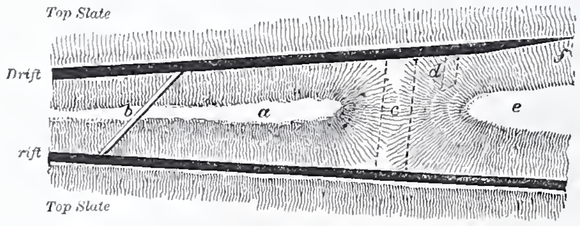


Fig. 139.—Section of Coal, No. 6, Rhume Run.



a, Anticlinal axis ; b, Tunnel ; c, Drift through Coal 72 ft. ; d, Do. 42 ft.

Fig. 140.—Ground-Plan of Old Mine in the No. 6 or Thirty-nine-feet Coal at Rhume Run.

plan of the mine, are instructive as illustrating the remarkable local alterations in thickness which coal-beds often present where they have been subjected to violent contortion and disturbance,

No. 7. The *Twelve-feet Coal,* the real thickness of which is 12 feet, contained, in the old drift-mines, only about 3½ feet of good coal. The distance of its outcrop from No. 6, the last described, is 183 feet, and the dividing strata are 129 feet thick. Upon the bottom-slate rests about 6 inches of soft coal or "dirt," and upon this the bench of good coal of the dimensions just stated, then an inch or two of slate, and above it the top bench of coal, which is of the kind called *bone coal,* and is not saleable. It is stated that at the end of the gangway, now closed by the falling of the roof, the lower bench of Coal-measures is 8 feet in thickness. The average course of this bed is E. and W., and its dip 48° S.

No. 8=7 *inverted.*—The *Pencil Coal,* distant from the last described 241 feet in a horizontal direction, and in the direction perpendicular to the dip 178 feet, owes its name to the pencil-shaped fragments into which it splits. Its thickness is uncertain, as it has never been regularly entered externally by drifts. In the several shafts sunk upon the outcrop it nowhere exhibited more than 4 feet of coal. The dip of this bed is assumed to be 48° S. Its irregularities and peculiar fracture are due to its being inverted and greatly squeezed by a synclinal fold between it and the Twelve-feet Seam, of which it is the counterpart.

No. 9=6. *Brown's Coal* has a total thickness of 10 feet. It is distant horizontally from the Pencil bed 111 feet, and is divided from it by about 82 feet of rock. This vein was originally opened on the E. side of the ravine. Upon the bottom-slate it there showed about 1 foot of coal-dirt, and above this 5½ feet of soft and somewhat crushed coal unfit for the market; next, 6 inches of slate, then 1 foot of coal, again 6 or 8 inches of slate, and upon the top of this 2 feet of bony coal. In pursuing this vein a short distance, the coal became much crushed, and therefore very inferior. This crushed condition of the coal is accompanied by a want of parallelism of the top and bottom slates. The average dip of the bed seems to be about 50° S., but it is very irregular, the strata in this vicinity being all inverted, and forming the S. side of an oblique or folded synclinal trough.

The *Proved Coal,* not enumerated among the coals cut in the tunnel, perhaps from being too thin to mine, outcrops 127 feet to the S. of the last, with 109 feet of interposed strata. It is probably not thick. It is not exposed in the cutting at the railroad, but, unless some error occurred in tracing it, the outcrop was opened on both sides of the ravine; and according to the superintendent, it there displayed about 15 feet of coal; but as the bed could only be regularly mined by entering it by a cut of considerable length through hard sandstone, it was not further developed. The dip of this bed appeared to be a little N. of the perpendicular—that is to say, less overtilted than the last described.

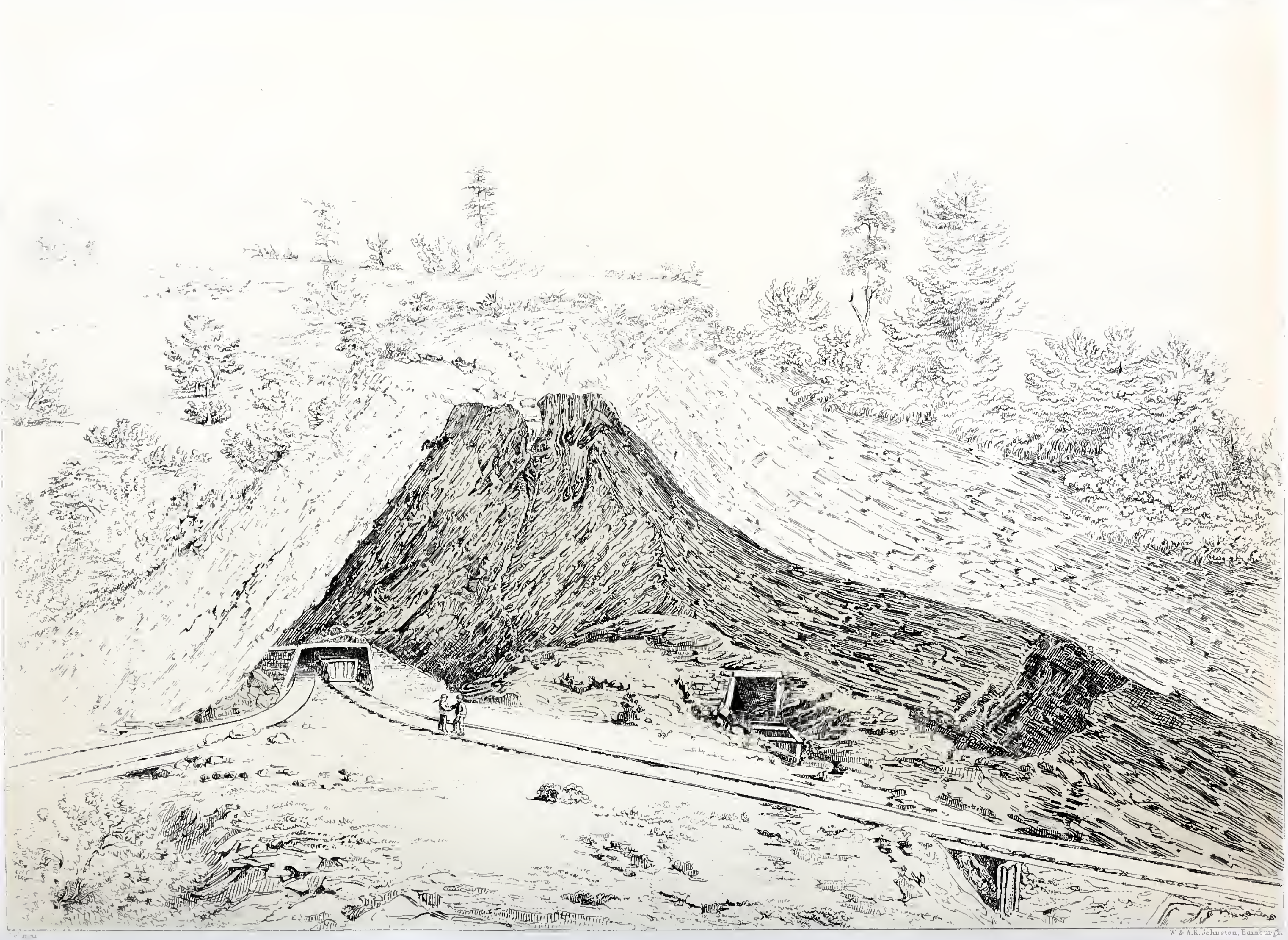
No. 10=5. The *Vertical Coal,* so called, has in reality a dip of about 60° N. Its distance from the Proved Coal is 87 feet, and the space of rock between them 80 feet. Although, like all the beds in this portion of the section, somewhat variable in its dimensions, its average thickness is about 15½ feet. The estimated thickness of its good coal in the tunnel is 8 feet. Upon the bottom-slate lie about 2 feet of coal-dirt and of soft crumbly coal, succeeded by 8 feet and 2 inches of good coal, containing two thin seams of slate. This 8-feet bench of coal alone is fit for market, for the remaining upper 5 feet of matter is composed of alternating layers of slate, bony coal, and soft crumbly coal. In some spots the bed was 26 feet thick, but the coal in these slipped places was unfit for general use. This description relates to the E. side of the tunnel; on the W. side it is in too crushed a state to repay the cost of mining.

No. 13=3. The *Fifty-feet Coal*, so termed, rises to the day in a saddle or anticlinal axis, and is well exposed on the E. side of the ravine. (See Plate for a picture of this curious arch of coal.) The horizontal distance of the axis, or more properly of the top of the North-dipping leg, is 236 feet S. of the Vertical Coal, and the distance perpendicular to the dip is 205 feet. On the N. side of the axis the average dip is 60°, on the S. side it is 45°, but the N. leg changes its rate of dip from 60° to 45° as it ranges Eastward in the mine. Both legs of the arch have been mined on the E. side of the railroad, but only the N. one successfully. The bed is penetrated from the ravine by three drifts at the water-level, where the rapid slope of the gorge has made an inclined plane necessary upon the railroad. One of these drifts is on the N. leg, one on the axis, and one on the S. leg. The axis, as might be naturally anticipated, rises Eastward, or towards the compressed and shallow end of the coal-basin. Therefore, in pursuing the coal in that direction, the levels or drifts gradually recede, the span of the arch widening, of course, as it rises above its previous level. To get access to the S. leg from the gangway, which is upon the N. one, two tunnels have been driven across from the one to the other. These tunnels are about 250 yards asunder; that nearest the mouth of the mine lies altogether in the coal, though its length is between 60 and 70 feet.

This is because it cuts across the flattened top of the anticlinal or arch, where the whole breadth of coal in it has risen to the level of the drift. The other more Eastern tunnel, lying upon very nearly the same level, intersects 167 feet of sandstone between the two legs of the arch, showing conclusively that its axis ascends in that direction. This is confirmed by the fact that, on the W. side of the ravine of Rhume Run, the axis or summit of the bed is much lower than on the E. so that it soon gets out of reach in that direction by passing below the water-level. Here the anticlinal axis is double, the slight depression in its centre, seen on the E. side, being here much deeper, passing into a steep synclinal roll, with much confusion and crushing of the inclined coal and roof. This very interesting bed, the identity of which with the Main Lower Coal, already described, cannot be doubted, has about the average dimensions of that seam, although the two legs of the anticlinal arch differ considerably in their thicknesses. The N. leg measures about 22 feet, and the S. one as much as 29 or 30 feet. The probable cause of this inequality is that the South-dipping part of the bed has slipped or yielded in the plane of the stratum, and the coal has thereby become crushed and broken so as to loosen the whole mass, and leave it in a more bulky state.

This coal in the tunnel and S. leg is crushed, but that in the N. leg is very good. In the N. leg the bed consists of 9 feet of good coal, overlaid by 5½ feet of inferior dirty coal, and this by 4 feet of good coal again, the rest of the mass being slaty. This is equivalent to 13 feet of good coal.

In the tunnel the order of things is this: The coal rests upon a stratum of sandstone, and consists of 6 inches of crushed coal, then 3½ feet of rather bony coal, next 2 feet of slate, upon this 1½ feet of inferior coal, and above this nearly 8 feet of good coal, with a little slate. Com-



W. & A.K. Johnston, Edinburgh

SADDLE COAL VEIN NESQUEHONING MINES.

paring the quantity of pure coal here given with that in the Main Lower Coal, we perceive that the aggregate is nearly the same. The introduction or disappearance of a little slaty matter may cause all the want of agreement witnessed between the two outcrops in the order of the benches of pure coal and slate.

Figure 141 is a diagram of the bed where the shorter tunnel intersects it.

No. 16 *of Tunnel.*—The *Second Southern Coal*, or first thick one S. of the axis, is distant from it horizontally 562 feet, and separated from this great anticlinal bed by about 322 feet of strata. Its thickness is about 15 feet, agreeing with that of the Vertical Coal, of which it is probably the South-dipping portion, the discrepancy in the distances from the axis arising perhaps from the squeezed condition of all the rocks on the N. side of the anticlinal. This bed yields about 10 feet of good coal in two benches, the lower one 6 feet thick, and the upper one 4 feet. The roof-slate is insecure. The dip of the bed is from 25° to 30° S. In Tunnel No. 2 it is evidently squeezed.

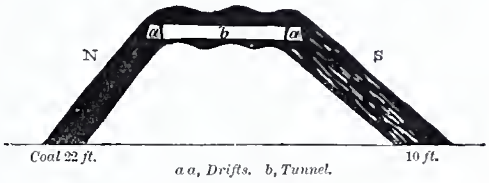


FIG. 141.—Saddle of the Big Coal of Rhume Run at the Short Tunnel.

No. 17 *of Tunnel.*—The *Third Southern Coal* has its outcrop 147 feet S. of the last named, and is divided from it by about 73 feet of underlying strata. At its outcrop it appeared to be about 10 feet thick, but no good coal was procured from the short drifts by which it was penetrated. In Tunnel No. 1, however, its average thickness is 13 feet, but the quantity of marketable coal in it is doubtful. There can hardly be a doubt that this and Brown's Coal are the opposite anticlinal portions of one bed. Its distance across the dip from the First Southern Coal coincides very nearly with that of the Proved Coal above the Vertical Coal, and it is possible that it may be the other leg of that seam. Its dip is from 22° to 30° S.

No. 18 *of Tunnel—Fourth Southern Coal.*—Another coal occurs, S. of that last described, in the tunnel, where it has not yet been mined, but seems to measure in horizontal thickness 14 feet.

No. 19 *of Tunnel—Fifth Southern Coal.*—In 1853 the tunnel terminated in a coal-seam 11 feet thick.

In the foregoing description of the coal-beds, it has been shown that the anticlinal axis seen in the saddle of the so-called Fifty-feet Coal rises going Eastward. When we pursue this anticlinal in the opposite direction, we therefore observe that it no longer lifts to the surface the same great lower bed (No. 3) ; and about three-fourths of a mile from the mines the next higher coals (the "Vertical") and the First Southern beds unite over the axis, both of the legs of which here dip at angles of about 30°. There are indications also that the next superior beds saddle the axis a little further to the Westward. The flattening-down of the dips on each side of this axis shows that it is already contracting and sinking. We shall see hereafter that its influence in the Panther Creek Valley, where it expires, is comparatively unimportant on the larger coals above the water-level. We know that it does not reach the Little Schuylkill, but dies out W. of Coaldale. It is, in fact, one of those many folds in the strata so common towards the terminations of the large synclinal troughs or basins which present a steep dip, or, in other words, a close compression of the rocks in the narrower end of the trough.

From the Nesquehoning Mines there were sent to market in 1856 about 64,291 tons of coal.

BASINS OF PANTHER CREEK VALLEY OPPOSITE SUMMIT HILL, OR BASINS *A*, *A* *A*, AND *B*.

(SEE SECTION THROUGH SUMMIT HILL.)

After what has been already detailed of the position and ranges of the two anticlinals A and A, which undulate the strata in the upper valley of Panther Creek, the limits of the three several subordinate troughs *A*, *A* *A*, and *B*, contained within the wide general basin N. of the Summit Hill axis, will be readily understood.

Locust Mountain Basin A.—This synclinal, composed of the South-dipping strata of the flank of the Locust Mountain, and the North-dipping ones of the axis A, which passes near the mouths of the Tunnels Nos. 6, 7, and 8, is, as the Map and Sections will indicate, very narrow on its S. side, and wide on its N., from the great difference in the inclinations and heights of the outcrops of the strata.

From the Hell-Kitchen Gap at Nesquehoning, eastward, this basin is, as already seen, the sole synclinal of the Coal-field, for by the disappearance of the anticlinal bounding it on the S. in the flank and crest of Sharp Mountain, it comes to be bounded on the one side by that barrier of the whole Coal-basin, while on the other it retains as its limit the barrier of the Locust Mountain. The belt carries its trough-like structure to the vanishing of its synclinal W. of Coaldale. The synclinal axis coincides nearly with the abrupt turn which Hell-Kitchen Creek makes Northwards toward its notch in Locust Mountain. It is seen again in the long Nesquehoning Tunnel, and it coincides very nearly with the bed of the Middle Western Brook of Rhume Run or Nesquehoning Creek. Passing over the table-land of the watershed into Panther Creek Valley, it ranges alongthe depression in which flows the North Branch of Panther Creek, and crosses very nearly at the mouth of Tunnel No. 6. We meet it next within Tunnel No. 7, a few hundred feet from its mouth, and again inside of Tunnel No. 8, about twice as far back from its entrance.

Within half a mile or more further W., the basin, as such, ceases by the cessation of the bounding anticlinal, its N. dip flattening down, and turning into the prevailing S. dips of the slope and foot of Locust Mountain.

Externally, that part of this basin which ranges from Tunnel No. 6 to Tunnel No. 8 is indicated by the middle of the flat terrace, or the plateau N. of the inner valley of Panther Creek; the brow or edge of this plateau being, as previously mentioned, the anticlinal summit of the wave A, of which this is the trough.

As in the instance of the corresponding wide synclinal belt *B* of the opposite or S. side of the Panther Creek Valley, there belongs to this trough a high mountain-breast of coal, and a low one ascending only to the summit of its neighbouring anticlinal; but in both instances these taller sheets of coal, so readily accessible from below by tunnels, offer very superb fields of the thick seam for mining.

Basin A a (Basin of the Bed of Panther Creek).—The central synclinal trough is occupied for the chief part of its length from the watershed of Nesquehoning and Panther Creek, westward, by the immediate valley of the latter stream. It is the narrowest of the three subordinate ones, being not much more than 1000 or 1200 feet in breadth. It evidently embraces the highest coals within the Coal-field—those, namely, of the lower Red-Ash group. The dips on the S. side of this trough are very steep, from the acute anticlinal flexure A south of it. Those of its N. side are more moderate, or about 45°, as the Section will make apparent.

Basin B.—The Southern one, B, is well defined by its topography, being bounded on the S. by the N. flank of the Summit Hill and the Sharp Mountain, where these become one, and on the N. by axis A, the S. of the two saddles, or that S. of Panther Creek. The central line of this trough is, for the chief part of its length, either a well-marked depression in the plateau S. of Panther Creek, or a flat portion of it, from Plane 2 eastward to beyond the old letting-down plane.

It is into this basin, the widest of the three subordinate ones, that the new Tunnel, No. 9, is now being driven, with a view to tap the great Coal-bed of the Summit Hill, descending into it with a N. dip.

Almost precisely at the synclinal axis, the roof of this tunnel fell in where the soil was more than 50 feet above it. Though the summit of the narrow anticlinal ridge intersected by the tunnel has an elevation of 80 or 90 feet above Panther Creek, and exposes the solid strata, the material from the roof of the tunnel to the surface in the synclinal proved to be wholly soft clay and included fragmentary drift. From this axis of the basin to the assumed point of intersection of the large Coal-bed, at the tunnel level, the distance is estimated to be some 1500 feet, the place of the synclinal axis being 600 feet S. of the tunnel's mouth. The Coal-beds cut in this tunnel at the synclinal axis are the small Red-Ash seams of the immediate basin of Panther Creek, or those which pass S. of the mouth of Tunnel No. 8; but what their precise equivalents may be, we have no means of determining. The dips on both sides of this basin are very steep.

Basin B C, or Basin of the Lehigh Summit Mines.—This basin, enclosed between the Sharp Mountain and the axis B, or anticlinal of the Summit Mines, presents the extreme E. point of its Coal-measures at the Breaker east of the East Summit Mine, or nearly opposite the notch in the Sharp Mountain. Its conglomerate-border ends in Mount Jefferson. It gradually widens and deepens W. Its central line ranges along the hollow between the Sharp Mountain and the Slope Mine No. 2, beyond which point we cannot trace it with precision, though it undoubtedly extends to the Little Schuylkill at Tamaqua. Viewing the most N. of the Tamaqua anticlinals as that of Summit Hill prolonged, it is apparent that on the Little Schuylkill there are three saddles embraced within the general synclinal belt or coal-field. The most S. of these, the Mine Hill axis, may extend E. in this basin to the Sharp Mountain, but the obscure condition of the surface S. of Panther Creek does not allow us positively to assert this. There is a hitch in the crest of the Sharp Mountain about one mile E. of the Summit Village, which I am strongly inclined to regard as the running-out of the Mine Hill anticlinal. If so, the true Summit Hill trough will be that of the immediate valley of Panther Creek, opposite the Greenwood Breaker, and thence W.; and the S. synclinal of Tamaqua, at the N. foot of Sharp Mountain, will be an independent basin to the S. of this one.

As it is impossible, in the present imperfectly-developed state of the coal-field, to pronounce positively which of the two anticlinals N. of the town of Tamaqua is the main Summit Hill axis, it is equally impossible to determine to which of the main basins, whether that of the Coaldale Valley or that of Summit Hill, the narrow enclosed trough contained between these two axes belongs, or rather into which of them it ranges.

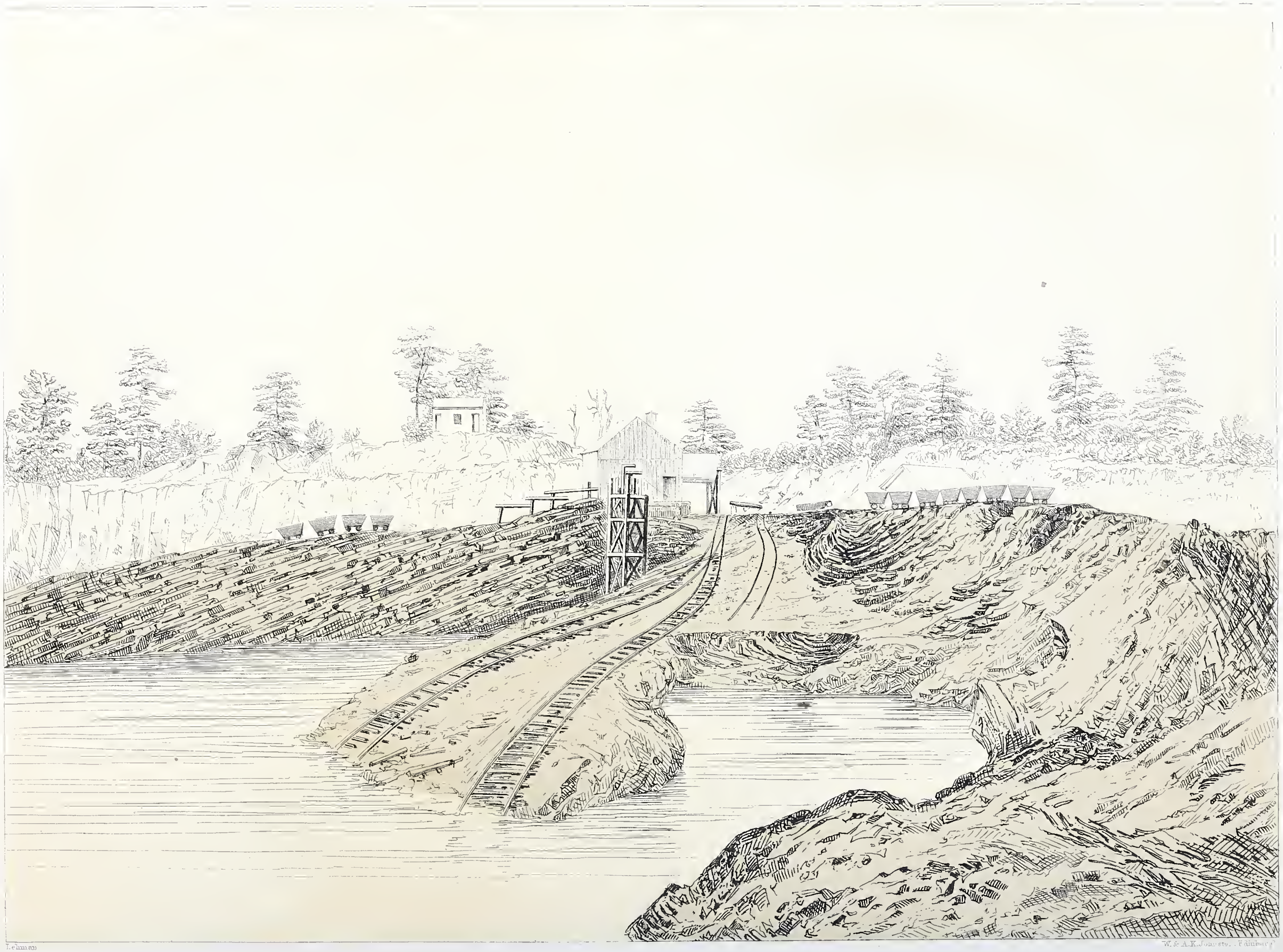
Summit Mines of the Lehigh Company, Basin B C.—Advancing W and S. along the coal-field, the next locality at which the strata are sufficiently uncovered to render a detailed description of them instructive, is that of the great open quarry of coal called the Summit Mine of the Lehigh Company. The general continuity and range of the coal strata from the extreme E. end of the basin near Mauch Chunk to this spot has been satisfactorily proved by the discovery at many intermediate places of ample masses of coal, but the extremely accessible position of the coal at Nesquehoning, Panther Creek, and the Summit Mines, has hitherto prevented the Lehigh Company from opening up any other portions of their vast coal estate.

The Summit Mines are situated about 8½ miles W. of the Lehigh River at Mauch Chunk, about 4½ miles from the Nesquehoning Mines, and not quite 6 miles E. from the Little Schuylkill at Tamaqua. Their position is on the S. margin of the coal-field, on an elevated table-land or shoulder of the Sharp Mountain, the adjacent narrow crest of which, as marked by the rugged outcrop of the conglomerate, rises but one or two hundred feet above the general level of the old open mine or quarry. From the margin of the open mine to the level of the Lehigh at Mauch Chunk the descent is 936 feet. Notwithstanding this difference of level, a railroad has long been in successful operation, conveying the coal from the mines to the Lehigh navigation, the motive power being the gravity of the loaded cars. Formerly the reascent to the mines was accomplished by mules, who descended in their own trains to Mauch Chunk to be ready to pull back the empty cars. This well-constructed road is interesting in the history of the internal improvements of the United States, as being the second railroad of any description built in the country, the first being the short road from the granite quarries of Quincy to the water-side.

There is a table-land or wide elevated flat at the mines, about half a mile broad, measured from the base of the crest of the Sharp Mountain. From its N. brow the ground descends in a long and steep mountain-slope to Panther Creek, which occupies the position of the general synclinal axis of the basin. This flat, united to the Sharp Mountain on the S. and E., as indicated upon the Geological Map, is separated from the Sharp Mountain on the W. by a dell or depression, drained by a little tributary of Panther Creek, called Coal Mine Run. This jutting forward of the shoulder of the mountain towards the W. arises simply from the presence of the anticlinal axis B, which, starting from the Sharp Mountain, or rather from its S. flank, recedes from the mountain as it extends W., and holds up the Coal-measures over the breadth of the flat. The W. spur-like termination of the flat is caused by the W. declension of the anticlinal axis. Whether this anticlinal extends to the Little Schuylkill is, as we have already said, somewhat uncertain.

The position of the coal and general structure of the basin at the Summit Mine is shown in the general transverse section of the coal-field (see Plate VI.), upon inspecting which, it will appear that the strata forming the flat undulate in one broad wave, with several lesser sharp folds in the S. side of the basin, due to compression from the steep uplifting of the conglomerate of the Sharp Mountain. The N. flank of the wave pitches steeply into the valley of Panther Creek, while the strata rise at the base, and upon the S. slope of the Locust Mountain. Upon the summit flat these undulations expose only the two lowest coal-beds, all the rest having been swept away by denuding waters. Of these lower beds, the second alone is important, but its dimensions and value are unsurpassed; it is that which is so extensively laid open to the day in the Great Summit Mine. The other bed, only 3 feet thick, has been proved, it is alleged, between the mine and the conglomerate of the Sharp Mountain, and it is therefore lower in the series than the large mass of the open mine, and is probably at the very base of the Coal-measures.

Our sketch (see Plate) conveys a good general conception of the position and extraordinary dimensions of the main bed of the Summit Hill. The picture embraces in its foreground the N. portion of the great open coal quarry, the beholder looking towards the W. On the left is the narrow crest of the Sharp Mountain, in the middle distance lies the centre of the coal-basin occupied by Panther Creek, in the background range the valley W. of the Little Schuylkill and



Lehman

W. & A. K. Johnston, Edinburgh

LEHIGH SUMMIT MINES. EAST MINE.

Locust Mountain, the N. boundary of the coal-field. The great coal-bed, in its total thickness, measures about 55 feet, and a large portion of it, certainly more than 30 feet, is coal of superior quality. The mass is composed of separate beds of pure coal of various thicknesses, separated by included layers of more earthy coal and bands of slate. Its constituent seams of pure coal and of slate show a great general persistency throughout the mine; and this fact, in connection with others to be presently mentioned, lends a high degree of probability to the opinion already expressed, that the unusual thickness of the bed is the result of a union of several of the large beds of the lower part of the series, by the mere thinning-away of their dividing strata.

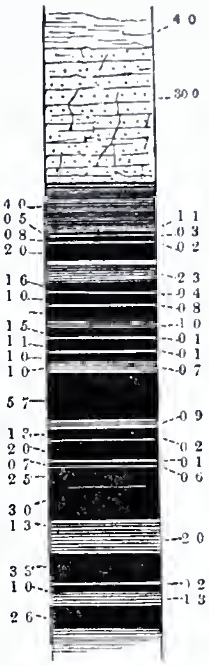


FIG. 142.—Subdivision of the great coal-bed of Summit Mines.

This open part of the great mine discloses the saddle or summit of the broad anticlinal axis B. Upon the very summit of the arch the coal itself comes to the soil in some places, and it was here, towards the E. point of the basin, that the excavation first began. In these naked spots the Anthracite was in the state of a fine black powder or sand to a depth of even 2 or 3 feet, and under it, for several feet, the coal was loose and fragmentary. As the work extended N. and S. from the crown of the arch, the overlying sandstone grew progressively thicker, until it amounted upon the N. slope to a covering of more than 30 or 40 feet, up to which thickness it was removed and the coal quarried under the open day. This process has now ceased, as the mining is all subterranean, by slopes and tunnels.

The floor upon which this enormous bed of coal rests, is the compact sandy fire-clay or shale so usually met with in this position. The cover, as in very many instances in the anthracite Coal-measures, is a somewhat firm, yellowish, and green sandstone, and not the laminated black slate, which in other fields forms the more usual roof stratum of the coal-seams. Here the sandstone lies in intimate contact with the coal, not the thinnest seam of slate or argillaceous matter being interposed, and the granules of sand at the lower surface of the rock have even numerous specks of the anthracite mingled among them.

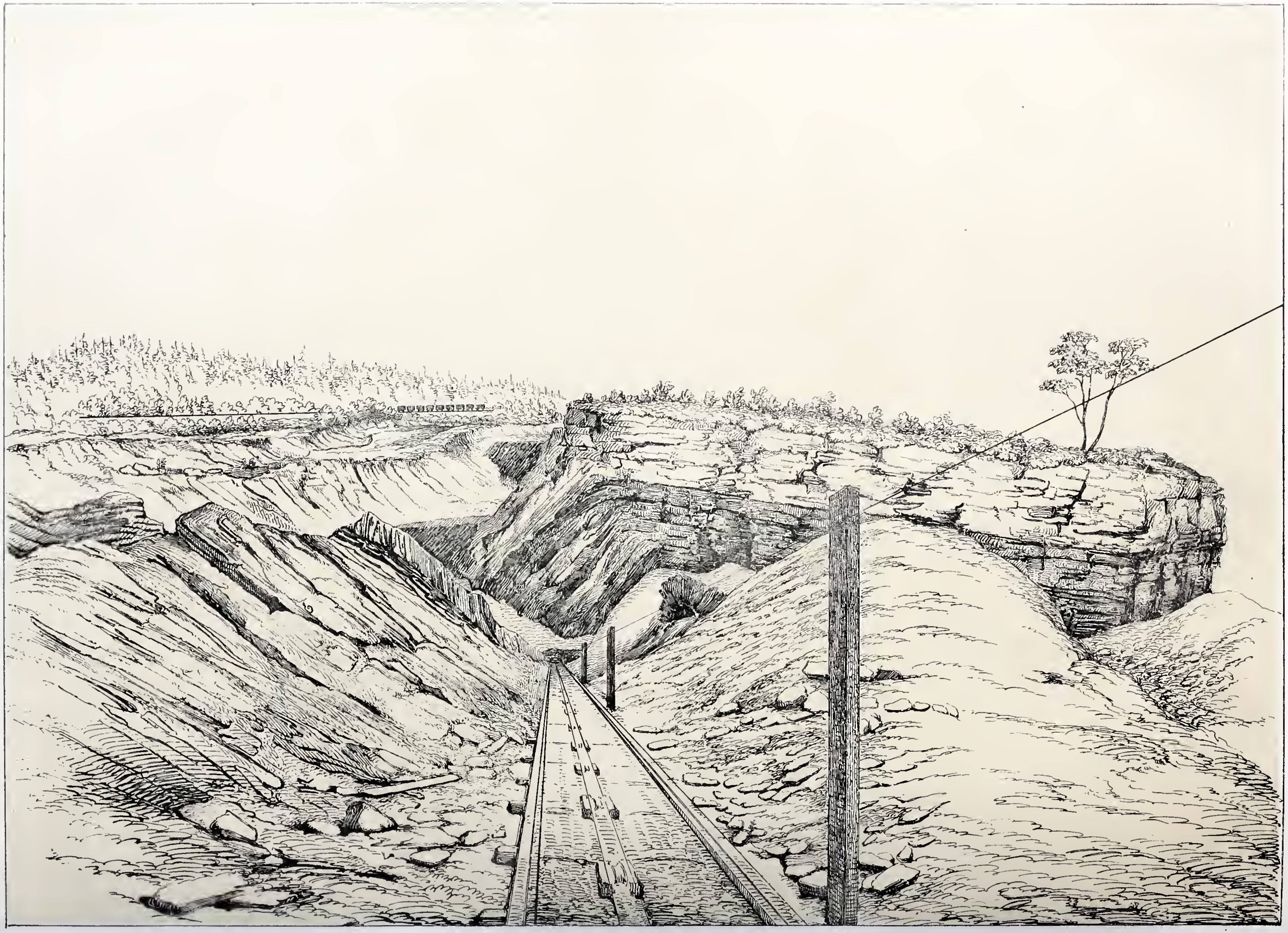
This great excavation of coal, only one portion of which is included in the picture, as it showed itself in 1841, then occupied an open area of probably 45 acres, but the uncovering continued until the quarry engrossed more than 50 acres. The waste coal and rubbish were conveyed Northward out of the quarry by short railroads to the brow of the hill, overlooking the Panther Creek Valley, and there piled until some truly enormous hills of it were accumulated. But it was found necessary at last to deposit the rejected matter within the area from whence the coal had been quarried out, which caused this to lose its once very striking and picturesque features. Many portions of its almost perpendicular walls are still standing, however, showing black cliffs of solid coal for a height of more than 50 feet, overtopped by a wall of yellow sandstone of a nearly equal additional height.

To the E. of the principal quarry, and rather nearer to the crest of the Sharp Mountain, lies the smaller mine, where also several acres of the great coal-bed were uncovered. This is situated upon the Southern margin of the basin, near its Eastern end, at what is apparently a subordinate anticlinal, the arch of which is however more crushed than that of the gently-curved axis of the Summit Mine. Between these two anticlinals the coal is nowhere very deep below the surface. Our sketch of the East Mine, so called, shows it at a time when it was not wrought, and was half filled with water; the other sketch displays its condition in 1853, after the mining had been resumed. As the coal gradually dips Westward, away from the level of the plateau, with the declension of the anticlinal arch and the surface of the ground in that direction, and as it laps regularly round the end of the broad spur in which the table-land terminates, sinking in level towards the bed of the valley both N. and W., there will be, as the mining advances, a continually-increasing lift to overcome, before regaining the summit of the present railroad at Summit Hill, E. of the mines. So also as the mining advances Westward, down Panther Creek Valley, it will be necessary, ultimately, either to send all the coal to market by its more natural outlet, through the valley of the Little Schuylkill, or to surmount the ascent to the present summit by locomotive power in addition to the present stationary power and inclined planes, or else by both means convey it to the Lehigh, by the gorge of the Nesquehoning, and thence over the present railroad from the Rhume Run mines.

An unexaggerated estimate of the average working thickness of the coal in the coal-field, between Nesquehoning and the Little Schuylkill, deduced from the actual experience of the mines, makes the total to be about 40 feet. At this rate every available acre contains not less than 65,000 tons of coal.

It will be seen, as we proceed in the detailed description of the Coal-measures of the several districts of the basin, that there everywhere prevails, low in the series, or within a few hundred feet of the main bed of conglomerate, one or more very large beds of White-Ash coal; and a comparison of the data connected with these remarkable outcrops shows that, though they do not all appertain to one continuous stratum, they are all approximately on two or three contiguous horizons, sometimes one, sometimes another, expanding to unusual size, often by admission of adjoining smaller beds.

The only question open to discussion is, whether, in an instance like that of the huge mass of the Summit Hill mines and Panther Creek tunnels, where the bed possesses very unusual thickness, the expansion of its size is caused by the merging into the principal bed of other adjoining coal-seams through the thinning-away of the dividing strata, or is merely a local enlargement of the one coal-bed between the same roof and floor, arising from more active deposition at this spot of the vegetable materials which formed it. If we were in possession of any complete sections of the lower Coal-measures, such as those of the Nesquehoning and Tamaqua coals, illustrative of the condition of things nearer to the Summit Mine than these localities, we might, from such data, possibly determine the running together or not of some of those beds to form this great deposit; but no intermediate points have been developed, and the distance of the two localities named, one 4½ miles and the other 5 miles, is too considerable to permit us to institute any close comparison between the individual beds at either of them, and that of the Summit. To explain the unusual thickness of the great bed by the coalescing of several large seams of the Nesquehoning group, we must assume, if we take the "main lower coal" and the two next which overlie it, as those which have here come together, that there has occurred a total exhaustion of about 134 feet of included rock; or, if we suppose only this "main lower coal," and the double or "Rowland's coal," to have united, we have still to conceive of the thinning-out of at least 77 feet of sandstone, in a range of only 4½ miles. A like difficulty besets us when we consider the thick plates of sandstone and slate which we must assume as having disappeared between the Little Schuylkill and the Summit, if we would derive the great bed from the coming together of any two or more of



EAST WORKINGS IN OLD LEHIGH SUMMIT MINE

the principal lower seams of that locality. Nevertheless, so much more uniform are the coal-beds generally than the mechanically-derived sandstones,—so much more easy is it, when we advert to the respective circumstances under which these two classes of deposition originated, to ascribe a rapid variation of thickness to the wildly-strewn strata of sand and pebbles than to the slowly and gently accumulated layers of vegetation of the ancient carboniferous marshes—that I strongly incline to that view which assumes the apparent alteration of thickness to be due to the thinning-out of the arenaceous rocks.

The total product of the Summit Mines of the Lehigh Company, for 1856, is stated to have been 284,711 tons, and for the past year (1857), 306,396 tons.

Coals of Panther Creek Basin and Saddles.—It has been already mentioned, that the Coal-measures of the Panther Creek Valley include, in the vicinity of Tunnel No. 8, coals as high in the series as the first or lowest five or six beds of the Red-Ash group. It is obvious that these basin out in succession along each trough in advancing Eastward, the uppermost first. And it is equally plain, from the structure of the district,—the disposition in echelon of the several basins, each more Southern trough and saddle originating further W. in Sharp Mountain,—that the same coals terminate always sooner going Eastward in the more Southern belts than they do in the more Northern. Where the lowest Red-Ash coal finds its E. limit in the first of these basins, *B*, at the foot of Summit Hill, is not precisely known ; but we may fairly infer it to be far E. in the hollow of the S. branch of Panther Creek, or even on the table-land beyond it. We know that the Nesquehoning coal, No. 3, or the 28-feet bed, is elevated to above the high-water level of the Nesquehoning Creek, in the 2d or N. anticlinal, A, and that even there the height of the table-land W. of this arch of the coal is sufficient to give a cover to the first of the Red-Ash coals. On this anticlinal A, therefore, the Red-Ash coals extend thus far at the least to the E. But on the other shorter and more subordinate axis, next S. of it, the probability is small that they range so far, or that they pass beyond the hollow which encloses the source of the S. branch of the Nesquehoning. It is indeed just in range with this axis that we have on the edge of the plateau, at the foot of Sharp Mountain, in the line of the tunnel, the outcrop of the large Nesquehoning White-Ash coal, the smaller anticlinal having probably ceased somewhere to the W. of this. Along both the anticlinals of Panther Creek Valley, in its enclosed synclinal trough of the immediate valley of the stream, we may trace, by fair inferential evidence, the presence of the Red-Ash coals, which are thus undulated in this central tract of the general basin, in four alternate N. and S. dips.

In the most Northern of the subordinate troughs, Basin *A*, or that intersected by the tunnels No. 7 and 8, the higher of the embraced Red-Ash coals must throw themselves out Eastward—the highest of them in the valley of the N. branch of Panther Creek ; while the lower rises more forward, no doubt, across the plateau to the Nesquehoning and the Hell-Kitchen creeks, and preserve their stations within the central belt of the basin, even much further E., perhaps to within a mile of the meridian of the Old Mauch Chunk Tunnel, near to which the Great Summit bed, or rather the large Nesquehoning division or branch of it, is lifted at last nearly to the day in the centre of the basin, by the joint agency of a local saddle and the excavation of the surface.

Westward from Coaldale it is not needful to trace the course of the several coal-beds in detail. Those recognised on the Little Schuylkill, and at Greenwood Tunnel, are indicated on the Map, as far as identified by the working of the mines, or traceable by the natural benches and other features which mark the lines of outcrop. To the Map and Sections I must again refer the reader. It is fit, however, to define in this place the ascertained range of the guiding coal F, of the Tamaqua series, as this has been already quite extensively and connectedly mined, both E. and W. of the Little Schuylkill, and the more especially as it occupies that very important horizon in the Coal-measures which separates the White-Ash from the Red-Ash group of coals. It is fortunately both a very persistent coal-bed and an exceeding pure one, and is moreover of the valuable thickness of from 10 feet to 12 or 14 feet—circumstances which have led to its being more extensively developed by mining than any other seam in this portion of the basin, if we except perhaps the still thicker subjacent bed E.

This valuable coal is wrought at Tamaqua on both sides of the river, on the N. side of the basin, and is the vein called O of the S. side. It is likewise intersected in the Greenwood Tunnel, 1 mile E. of Tamaqua, and its identity fully established by tracing and by its relative position. From the Greenwood Tunnel eastward it has been mined above the water-level of the tunnel, a distance of at least 1½ miles, and is well defined at its outcrop by the bench or terrace which follows it, and by the series of air-holes driven through it to the surface. At Carter's New Slope, about 3000 feet E. of Greenwood Tunnel, this coal is opened below the level of the Greenwood Tunnel gangway, a slope depth of 300 feet or 500 feet from its outcrop. The furthest point to which it has been mined on the upper level is a mile nearly E. of this new slope, bringing it to within less than 2 miles of tunnel No. 8 of Panther Creek Valley. The position of its most Eastern air-shaft, at the date of observation, November 1853, is given on the Map. The day cannot be at all remote when the extension of the gangways Westward from tunnel No. 8 will enable us to identify this coal with one of those in the tunnel. That it will prove to be the main Red-Ash bed of that and the neighbouring tunnels there can even now be but little doubt.

The dips in this coal at its outcrop, as far as traced Eastward from the Little Schuylkill, are worthy of record, as displaying the more than usual regularity of structure which belongs to the N. side of the basin of Panther Creek. At Tamaqua the S. dip is 55°, in the Greenwood Tunnel it is 60°, and at Carter's New Slope it is again 55°.

This coal F will, in a future page, be identified at various successive points Westward from Tamaqua, as far at least as Palmer's Tunnel, W. of Tuscarora.

Basin D, or Basin of Sharp Mountain and Anticlinal Axis C.—It has been already stated, that an anticlinal axis passes through or originates in the Sharp Mountain E. of the head of Dry Hollow, and that, keeping S. of the Valley of Panther Creek, it extends towards the town of Tamaqua, and it was intimated that this, if not identical, is nearly coincident with the Mine Hill flexure which passes the Little Schuylkill on the S. edge of that town. Between this saddle and the crest of Sharp Mountain there is a slender basin in the Coal-measures, containing no coal S. of Dry Hollow, but expanding and deepening Westward to the Little Schuylkill, where it contains a full suite of coals, including all the White-Ash and several of the lower Red-Ash beds of the district. Except at the Little Schuylkill, the coal-seams of this sub-basin have not been opened, either experimentally or by systematic mining, and we shall therefore have no details to submit concerning them until we describe the Coal-measures as they are developed on the Little Schuylkill. Upon general considerations, it is obvious that the narrow Eastern half of the part of this belt, E. of Tamaqua, can contain none of the Grey or Red Ash coals, which can only enter the basin as we approach the Little Schuylkill. It must be somewhere within the Eastern half of this trough, probably opposite the Western half of the Dry Hollow Ridge, that the Big coal of the Summit Mines subdivides, to form a part of the White-Ash group, as seen at the Little Schuylkill. Judging from the condition of the Coal-measures on the Little Schuylkill between Tamaqua and the Sharp Mountain, this basin does not promise a large product of sound coal, notwithstanding the great dimensions at the surface, of its lower seams. The Sharp Mountain all along this portion of its course has its strata almost on end, and it is sufficiently apparent, that not only the coals between its conglomerates, but those at its N. base, are greatly squeezed. It is probable, indeed, that those near the synclinal axis, or turn of the basin, are even overtilted. What may be the condition of the Red-Ash coals, adjacent to the saddle C, which bounds the basin on the N., we have no means of positively judging ; but we are entitled to infer, that all the Red-Ash measures adjoining, and included between all three of the anticlinal axes of the centre of the coal-field at and E. of Tamaqua, and probably W. of it for some distance, are in too disturbed and crushed a condition to admit of being profitably mined, at least at the present day. It does not follow, however, that the subjacent or White-Ash thicker beds, enclosed between less flexible strata, are as sharply undulated, or as much crushed by sliding pressure.

THE COAL-MEASURES, UNDER THE SEVERAL LOCAL TYPES THEY PRESENT BETWEEN THE LEHIGH AND LITTLE SCHUYLKILL.

The Coal-measures, using this term to signify all the strata above the conglomerate, or that portion of the coal-formation which is productive in coal-seams of notable dimensions, display some unusual and very interesting features and fluctuations of type, as we follow them for the short space of 13½ miles, from their E. termination near Mount Pisgah to the Little Schuylkill at Tamaqua. Comparing the sections supplied by the Old Mauch Chunk Tunnel and the Nesquehoning Tunnels at the E. end, with those of the Summit Mines and Panther Creek tunnels, in the middle part, and with the Tamaqua Mines at the W. limit of the district,* we are forcibly struck with the very great disparity between them.

In the Mauch Chunk Tunnel, or most E. section, there would seem to be about ten or twelve separate beds of coal, of all dimensions, from 1 or 2 feet of thickness to 17 or 18 feet. And all of these, as far as we can ascertain, are White-Ash coals. So likewise in the Nesquehoning section (see Tunnel No. 1.), we find seven, or possibly eight, well-recognised coals, five of which are of thicknesses between 12 and 17 feet, while the two smallest are 3 and 4 feet respectively, and none of these are Red-Ash coals.

About 360 feet W. of Tunnel No. 8, the coal, usually 55 feet thick, grows thicker ; and at 600 feet, from the end of the gangway in 1852, it was from 90 to 100 feet thick ; but this is manifestly in consequence of a doubling or slipping of the seam upon itself.

At the Panther Creek Tunnels and the Summit Mines the coal is very differently distributed. The five or six upper beds of Nesquehoning are here, by all indications, united into one great stratum, which varies from 45 to 55 feet in its aggregate thickness. Thus far researches in the vicinity of the Lehigh Summit, and the parts of the Panther Creek Basin opposite to it, have shown that the whole of the White-Ash series is represented by this one great bed alone, with an insignificant coal-seam at a short distance beneath it. In the ascending order, the coals which next succeed the large bed are two thin *Grey-Ash* seams, and upon these repose five or six Red-Ash beds, the lowest of which, containing 10 or 11 feet of coal, is extensively mined in some of the Panther Creek Tunnels as a genuine Red-Ash coal.

---

* See the several sections and vertical columns of the Coal-measures at these localities.

Here, then, occurs a very extraordinary thinning-away between Nesquehoning and Panther Creeks, of all the rocks of the former locality, interstratified among the coals of the chief part of the thick White-Ash series. Not less than 350 feet of thickness of strata : coarse grits, argillaceous sandstones, and sandy shales and slates, have thinned down and disappeared within a space scarcely exceeding 3 miles. These rocks, if represented at all at the Panther Creek Tunnels and Summit Mine, are only to be traced in the thin partings or seams of slate and fire-clay, of which one only exceeds 2 feet in thickness, which separate the constituent layers of coal of the large mass. I think it every way probable, that the Nesquehoning coals, which thus unite to form the large bed, are the so-called Twenty-eight-feet, the Five-feet, the Nineteen-feet, the Thirty-nine-feet, and the Twelve-feet seams.

Turning now to the Tamaqua section, we behold a subdivision of at least the White-Ash portion of the Coal-measures, altogether dissimilar from either that of the Lehigh Summit Mines or that of Nesquehoning. Here the White-Ash or lower group, everywhere the most variable division of the Coal-measures, is now subdivided into no less than eight or nine important beds of coal, separated by thick strata of alternating sandstones, conglomerates, and shales—the individual spaces between the coals, filled by these rocks, being from 50 to 200 feet in thickness. Assuming the lowest of the Grey or Reddish Ash coals to be persistent throughout the district, as the facts seem to warrant, we are forced to regard the four or five upper thick White-Ash beds as only the prolongations of the subdivisions of the great bed of the Summit Mines, wedged further and further apart in their progress Westward by the constantly-expanding strata of the sandstones, shales, and conglomerates. I am disposed to view the Tamaqua coals B, C, D, the D cross-cut, and E, as all five of them united at the Summit Mines in the one great 55-feet-thick deposit. This hypothesis supposes that the bed A is represented at the summit by the solitary thin coal-seam beneath the larger mass, while the two still inferior ones of Tamaqua have thinned away Eastward altogether ; and it assumes the main conglomerate mass of the crests of Sharp and Locust Mountains, opposite the Summit Mines, to terminate upwards with the Nut conglomeratewhich, at Tamaqua, underlies the coal A : the other thinner and less coarse pebbly beds, interposed between coals A and B, and between B and C, having, with the other separating rocks, all dwindled away before they reach the Summit Hill and upper valley of Panther Creek.

The data collected do not permit us at the present time to trace the Grey and Red Ash coals further Eastward in the basin than the sources of Panther Creek—the shoaling of the basin seeming to have caused their denudation at the Nesquehoning Mines and everywhere beyond. An inspection of the Tunnel Sections of Panther Creek and of the Tamaqua Section will display the same number, usually two, of Grey-Ash coals, interposed between the White-Ash group and the genuine Red-Ash coals ; the first of the latter class being very generally, even indeed for many miles W. of Tamaqua, the third bed above the highest true White-Ash seam. The number of the proper Red-Ash coals evidently increases towards the Little Schuylkill, with the progressive deepening of the coal-field going W. Thus, we count about six such beds, from 1 foot to 7 feet in thickness, in the Westernmost Panther Creek Tunnel, or No. 8, and about nine of similar various dimensions at Tamaqua.

OF THE POSITIONS IN THE GENERAL BASIN OF THE SEVERAL GROUPS AND THE MORE IMPORTANT INDIVIDUAL COAL-BEDS.

It is not in our power, in the present undeveloped condition of this extensive valley, to speak with satisfactory precision, except in a few instances, of this very interesting part of the subject.

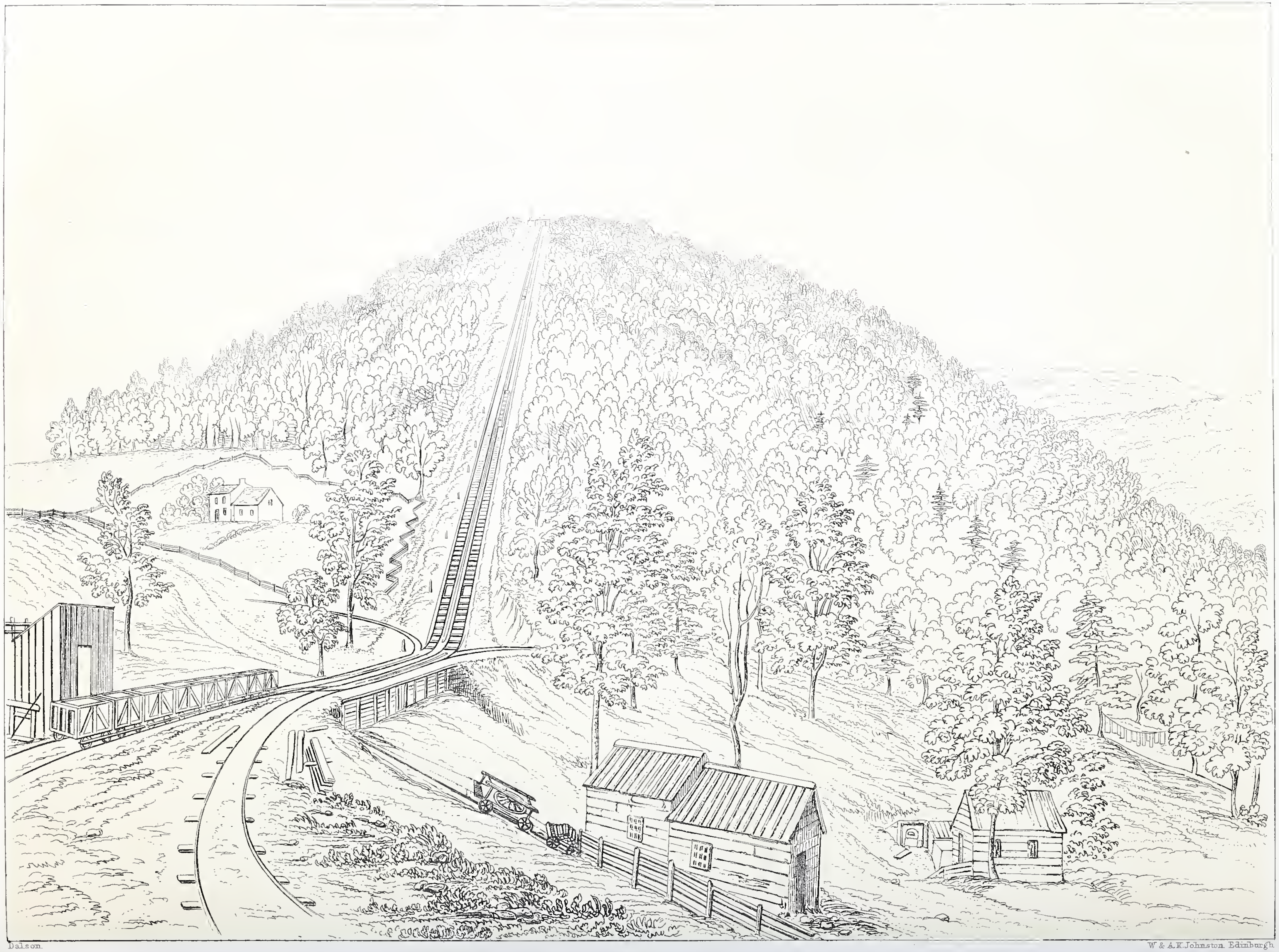
Beginning with the coals lifted to the surface on the arch of the Summit Hill anticlinal, the great summit bed, as already shown, converging its outcrops from the basin of the old mine on the one side, and from the flank of Sharp Mountain and N. side of Summit Hill on the other, unites near the head of Slope Mine No. 2, on the anticlinal axis. This axis declining Westward, the Red-Ash vein saddles it at a distance of a few hundred yards, at a point where the spur is rapidly descending opposite the village of Centreville, or about 1 mile W. of Slope No. 2. This declension of the anticlinal Westward, brings the Large Summit Coal at Tunnel No. 2, in the Dry Hollow Ridge, to a lower level than its place at the slope by several hundred feet.

Dry Hollow Ridge, having the axis within it, receives, between this anticlinal bend of the large coal and its crest, a sufficient thickness of Coal-measures—especially W. from the tunnel—to include several of the Red-Ash coals. And thus, notwithstanding the gradual Westward descent of its crest, three Red-Ash beds have been opened on it about three-fourths of a mile from the tunnel in that direction. Underneath them the large coal is no doubt far below the water-level of the valley. From the data embodied in the Tamaqua Section, we are enabled to approximate to the depth of the Great Coal seam at the Little Schuylkill on this anticlinal, or where it approaches nearest the surface, and the inference is, though it should be accepted with some latitude, that the coal comes to within perhaps 800 feet of the soil. The coals, which there saddle this axis above the water-level, are beds which belong to the middle division of the Red-Ash group. By the large bed we here mean, of course, only its upper member, or the coal E. of Tamaqua.

Coals of Summit Hill Basin, B, C.—Of the coal-seams contained within the basin enclosed between the Sharp Mountain and the above-mentioned anticlinal B, it is enough to state that the Great Summit bed has the E. end of its own basin E. of the New Mine at the breaker; and that W. of the Meridian of slope No. 2, the Red-Ash coals appear within it in successive concentric troughs, all deepening towards the Little Schuylkill, until, by the intrusion of the middle Tamaqua anticlinal, the centre of the trough is re-elevated to some unknown extent. The highest coals included in either branch of this basin at Tamaqua are seemingly those about the fifth or sixth in order above the upper White-Ash beds. These are, however, not mined on the Little Schuylkill, partly because they are to be reached only below the water-level of the valley, and partly on account of their less thickness when compared with the White-Ash coals. They are probably also more faulty, from being more involved in the anticlinal and synclinal flexures.

Arrangements of the Lehigh Company for Conveying the Coal of Panther Creek and the Summit Mines to Market.—The Lehigh Company has constructed many remarkable works for the transportation of their coal,—railroads, inclined planes, tunnels, locks, &c., chiefly planned and built by their very able engineer, Mr Douglas. Their system of conveying the coal from the Panther Creek and Summit Mines to the Lehigh Navigation at Mauch Chunk is so ingenious and successful as to merit a concise description here. Locomotive steam-power is entirely dispensed with, and recourse is had to inclined planes with stationary power, and to the propelling force of gravity upon railway tracks of a requisite gentle slope. Availing themselves of the singularly favourable physical features of the district, the Lehigh Company and their engineer completed, several years ago, a chain of gravity tracks and inclined planes, extending from Mauch Chunk to the Mines and back again to the Navigation in an endless circuit. It consists of two independently-planted, single-track railroads ; one for conveying the loaded trains from the Mines to Mauch Chunk, the other the empty trains back from Mauch Chunk to the Mines. Their routes, though somewhat different, intersect each other. The whole system will be readily understood by consulting the Map, and attending to the following description of the circuit which the coal-cars, loaded and empty, are made daily to perform. Let us begin at the remotest part of the line, say at Tunnels No. 6 or No. 7 in Panther Creek Valley. The coal-cars, after receiving their freights of coal, previously picked and screened near the mines, convey it, by force of gravity alone, upon a gently-inclined railway track, graded with an inclination of not less than 40 feet to the mile, along the immediate valley of Panther Creek to the foot of Plane No. 2. Here they are coupled into sets of three, and hoisted rapidly by ample stationary power to the summit of the plane. This plane has a length of 2030 feet, and a vertical lift of 250 feet. Collected at the summit of No. 2, they are allowed to run by gravity, under proper checks, E. to the foot of Plane No. 1, losing a little of the elevation they had gained. At No. 1, they receive a lift of 375 feet over a plain 2436 feet long. They are now at the summit-level between Panther Creek Valley and Mauch Chunk, their position being just on the anticlinal axis *B*, N.W. of the village of Summit Hill. From this point their course to Mauch Chunk is unobstructed, and they now start upon their journey over what is called the Loaded Track. They are made up into trains, not embracing more than sixteen cars in each train, controlled by a brakeman, who sits aloft, holding a rope to which the brake-handle of each car is attached by a shorter cord, and who is thus enabled effectually to bridle the whole, and they are sent on their journey by a push from the shoulders of two or three men. Starting off with a smooth and gentle motion, they soon acquire a rapid speed, which occasionally requires the brakeman to rein them in. They glide first across the head of the basin of the Summit, then Southward and Eastward round the flank of Mount Jefferson, and, passing under the inclined plane of that name, take the S. flank of Sharp Mountain, along which the loaded track, descending at an average grade of 40 feet per mile, now passes for about 3 miles, until nearly opposite Nesquehoning. There it diverges towards the valley of the Mauch Chunk Creek, which it pursues for 2½ miles further, when the creek, descending too rapidly, the railroad, to maintain its own grade, passes on the brow of a sloping table-land N. of the stream, along which it holds its course to the upper village overlooking the Lehigh, where the loaded trains come to a pause and are discharged. The terminus of the Loaded Track has an elevation of about 200 feet above the pool or slack-water of the Lehigh at Mauch Chunk, and this descent is overcome by the coal by the contrivance of a series of schutes, or inclined troughs, to be described presently. The total descent from the summit at the head of Panther Creek, Plane No. 2, to the surface of the water at Mauch Chunk, where the canal boats receive the coal, is 946 feet. From the summit of the Loaded Track to its lower terminus the length is about 8½ miles.

Having discharged their freights, the now empty coal-cars are conveyed, still by gravity, to the foot of the first lifting-plane of the empty or return-track. This plane ascends along the



Dalson.

W & A.K. Johnston Edinburgh

MOUNT PISGAH PLANE, MAUCH CHUNK.

E. spur of Mount Pisgah, an outlying terminating synclinal knob of Sharp Mountain. (See the Sketch of the Mount Pisgah Plane.) The perpendicular lift to the summit of the Back Track at the head of this plane is 825 feet. The cars are pushed up the plane by an ingeniously-contrived pushing-car or truck connected with an endless chain, or rather broad band of tough plate-iron, propelled by a stationary engine at the summit. The safety-car, as it is called, rests at the bottom of the plane below the level of the track, in a deep long trench or pit, and the empty cars, in requisite number, are shoved over it. At a signal given, the endless band is set in motion, and the safety-car drawn out of its pit to the rear of the empty train, which thus begins its journey towards the summit. The speed of the ascending train at Mount Pisgah is usually 370 feet per minute. From the summit of the empty track the empty cars descend at an average grade of 50 feet per mile along the S. flank of the Sharp Mountain, a distance of a little more than 6 miles to the foot of Mount Jefferson. There they are lifted by another inclined plane, No. 2, of the empty track, a height of 462 feet, at a speed of about 740 feet per minute, the plane having a length of 2070 feet. From the head of the Mount Jefferson Plane the empty track is continued to the village of Summit Hill, a distance of nearly one mile, with a grade of nearly 44 feet per mile. The rest of the journey to the mines is made by what is called the Back Track, which, setting off from Summit Hill, runs by two branches or separate routes into the Valley of Panther Creek. One of these diverging N., and crossing the anticlinal axis of the summit W. of the Catholic chapel, turns Eastward, and, descending the mountain obliquely, meets a zigzag or switchback track near Tunnel No. 5, beyond which it enters the immediate valley of Panther Creek, which it follows closely to our points of setting out, the breakers connected with Tunnels No. 6 and No. 7. The other, or Sharp Mountain Back Track, passes through the Old Open Mine to the head of Dry Hollow, which it recrosses by a switchback track, and then resumes its course until it turns Northward and Eastward over the anticlinal spur of the Summit axis, 2000 feet W. of Slope No. 2, till it reaches the head of Plane No. 2. Here the empty cars may either descend the plane, or, keeping the hill, pass Eastward to the foot of Plane No. 1, passing, in the interval, near the mouths of Tunnels No. 3 and No. 4.

A separate lifting-plane is employed to elevate the coal drawn from the bottom of the Summit Mine by Slope No. 2, and sent forward to the Main Loaded Track. This Plane, No. 3, descends North-westward from the foot of the conglomerate crest of Sharp Mountain. Its length is about 2200 feet, and the head of the plane lies not far W. of the S. quarry of the Old Open Mine.

The fall of the Back Track is about 300 feet.

Coal Schutes at Mauch Chunk.—At Mauch Chunk there are four schutes or inclined troughs for letting down the coal from the end of the railroad to the river. They are respectively 750, 700, 650, and 600 feet long, and their inclination is 1 in 3, or 17°. Their lift from the river is 213 feet to the Loaded Track. The fourth schute is a slide schute—a trough 5 feet wide and 4 feet deep, with gates 50 feet apart. The trough is ironed on the bottom with half-inch cast-iron plates 1 foot by 4 feet. There are eight gates. The coal is not materially injured by the friction, and what loss occurs is compensated for by the facility and saving in labour. There is also a large wooden schute from the plateau at the foot of the hill for small-sized coal, and within it are gates and a trough, with grates for Egg and Stove coal. Schute No. 3 has a short empty car or transfer-plane for lifting 15 feet to the general upper level of the Loaded Track. For want of room, No. 3 plane or schute is made to run under Schute No. 2, and therefore this additional lift of 15 feet. This is at right angles, and is done by a pushing-car; the weight of the loaded car acting through the drum and a lifting-shaft, to work a small drum at the head of the small transfer-plane. There is a spring and a beam at the top of the plane, in the edge of the drum-house which of itself comes on to the rail, and prevents the car from running down the plane.

Wire-ropes are used for the schutes; they are $1\frac{1}{4}$ inches in thickness; those for the large planes at the mines are $1\frac{3}{8}$ inches. They contain 36 wires of No. 14 wire. One foot weighs one lb. That of $1\frac{1}{4}$ inches diameter contains 6 strands of 19 wires each, or 114 wires; there is also a core or central rope of hemp; and here each strand has a wire-core, just as the English rope has a hempen core.

The Mount Pisgah Inclined Plane.—There are two engines at the head of this plane, working two drum-wheels geared to run in opposite directions, carrying the bands of the planes. These wheels are 27 feet in diameter, and are cogged on the periphery. The bands are two on each track; they consist of tough iron-plate, and each band is $6\frac{1}{2}$ inches wide, and $1\frac{1}{8}$ inches thick.

From the engine, a light shaft, geared by spur-gearing, works three pump-rods. Each pump has a different level on the side of the mountain, the water being lifted from the river.

Tunnels.—The Panther Creek tunnels have usually a fall of 6 inches to 100 feet.

Tunnel No. 5.—Its length is 849 feet, and about half-way in, it cuts Red-Ash coal 11 feet thick, with 3 feet of coal, the remainder being Bone-coal and slate. The dip is 70°. The coal has a twisted fracture. The total thickness of the Big Coal is 45 feet, with the same divisions as on the summit. There is rather more slate in the basin than on the summit.

The gangways are driven three-fourths of a mile Westward and one-fourth Eastward. The E. gangway of Tunnel No. 4 meets the W. of No. 5.

Tunnel No. 7.—The Big Coal is worked here, also the Red Ash. This tunnel enters Locust Mountain westward, a little W. of a point opposite Summit Hill.

Tunnel No. 8 (the longest in Panther Creek Valley).—It measures 1575 feet; the dip is about 42°. There are two or three small Red-Ash coals in this tunnel, and one at the mouth about 2 feet thick. The tunnel has a breast of 450 feet; the coal has been worked up 300 feet in some places. The gangways are driven 650 (yards?) both E. and W. It yields about three-fifths coal, and two-fifths dirt. It enters Locust Mountain westward opposite Slope No. 2.

The Red-Ash Vein in this tunnel is 7 feet thick, between slates, but will yield of good coal only 3 feet. It is the only Red-Ash coal worked here. The 11-feet coal above the large White-Ash Vein appears to be vein F. of Tamaqua and Greenwood Tunnel. The dip of the Big Coal is about 45°. The thickness at right angles to the coal is from 45 to 60 feet. This shows a considerable fluctuation in the thickness of this coal in short distances.

The Coal costs about $37\frac{1}{2}$ cents per ton to bring it from the mine; then about $12\frac{1}{2}$ cents to break and clean it. It then costs $12\frac{1}{2}$ cents to lift it to the summit, and run it to Mauch Chunk, and $12\frac{1}{2}$ cents more for other expenses. The engine of No. 8 Breaker is 20 horse-power. It hauls the coal up from tunnel-level to Breaker. Other Breakers have usually 10-horse-power engines. The Tunnel No. 8 is 13 feet wide, 8 feet high, has a double track at its mouth, and turn-outs within. The rails in the tunnel are of half-inch iron on wooden sleepers. One mule brings out three loaded cars.

Tunnel No. 9.—This important tunnel, designed to give access to the Big Coal dipping Northward from the anticlinal of Summit Hill into the main South basin of Panther Creek, or basin *B*, starts from a little above the water-level of Panther Creek, near Coaldale, and extends Southward about 2000 feet. It is the longest tunnel of this valley, and is one of the greatest in the coal region. It was begun in 1852. Not far from its mouth it passes the anticlinal axis A, cutting one or two of the Red-Ash coals. Farther in, it encounters the synclinal axis of basin *B*, where, as already mentioned, the crushed condition of the strata caused an extensive caving-in of all the materials above the tunnel-level to the surface, a height of some 80 feet. Beyond this synclinal turn the strata are regular the whole way to the conglomerate beyond the end of the tunnel, their dip being to the N. at a steep angle, averaging 55°. This farther half of the tunnel intersects the lower Red-Ash coals, the two Grey-Ash beds, and the Great White-Ash or Big coal, in which the excavation terminates. The mass of coal which it gives access to is very great, the Big coal presenting here a total thickness of more than 50 feet, and a length of breast or slant height between the tunnel and its outcrop, on the brow of Summit Hill, estimated at not less than 600 (?) feet.

Slope No. 2.—This is on the N. outcrop of the Summit Basin. It is about 243 feet to the water-level of the tunnel, then 10 feet of gangway, and 213 feet farther to the foot of the slope: the dip is about 37° S.

The machinery and openings *permit* a daily product of 1000 tons; the actual daily product is seldom so great. There are two engines of 40 horse-power each, for pumping and lifting the coal, and two others for the Breaker, of 10 horse-power each.

It is stated that the actual cost of lifting the coal from Panther Creek to Summit Hill is about four cents per ton; the lift, about 600 feet, is accomplished by two planes. This includes interest on planes, &c.

The coal of the N. side of basin is not quite so pure from slate as at the Summit Mine, and going still farther N. to the Beaver Meadow, the parting-slates are still thicker, but the coal there is somewhat purer.

The Lehigh Company has a capital of 7,000,000 dollars. This, and all their earnings since 1841, has been absorbed in extensions. The stockholders have in this interval received no interest. Their calculation for paying an interest was based upon coal selling at 5 dollars per ton in Philadelphia. It is generally below this price. The Company owns in all 20,000 acres, of which 15,000 lie in one body, extending Eastward from the Little Schuylkill at Tamaqua, to nearly 2 miles E. of the Lehigh, at Mauch Chunk. The other 5,000 acres are scattered up and down the Lehigh Valley.

CHAPTER III.

TAMAQUA.

COALS AND COAL-MEASURES.

In 1852 and 1853, when the whole S. anthracite field underwent a critical revision by the Survey, this locality was carefully studied, topographically and geologically, and, as in so many other localities, minute measurement of the strata instituted, and notes taken for the construction of an accurate Section. As now engraved, this Section embodies nearly all the data essential to a clear understanding of the structure and resources of this portion of the coal-field, except those which relate to the coals, as these are developed in the mines, and those of the mining statistics. The reader is therefore recommended to examine the Section for information not included in the following descriptions, which embrace rather the coals themselves than the rocks between them.

The fine natural section of the Coal-measures at Tamaqua, exposed by the transverse trend through the basin occupied by the Little Schuylkill, aided now by multiplied artificial mining openings, permits us to recognise almost every member of the large series of coals contained there. Above the main or lowest Seral conglomerate occurs, *first*, a group of *Eight White-Ash Coals*, the five lowest being separated respectively by coarse Nut-conglomerates with sandstones and shales, and the succeeding ones by less pebbly rocks. Between the lowest of these coals and the uppermost of the Umbral rocks, the Seral conglomerate group proper has a thickness of not less than 200 feet. The eight beds referred to terminate with the thick and noble seam designated by the letter E. Above this largest of the series, at an interval of more than 230 feet, succeeds the coal F, the first of the true Grey-Ash beds; and about 80 feet above this is the so-called Bony Coal, the second and last of the proper Grey-Ash group. Next in order is the Red-Ash Vein, so called, the lowest of the true Red-Ash class, of which we may count at Tamaqua not fewer than seven or eight. Thus the whole series amounts to seventeen or eighteen beds, the chief of which possess qualities and dimensions well fitting them for mining and for the market.

On the S. side of the basin only, the lowest thirteen or fourteen of these coals present themselves, dipping almost perpendicularly in the Sharp Mountain, and in the slope at its N. base. A crushed synclinal fold in the latter position repeats the higher members of this group in a steep S. dip, which gradually flattens until it is succeeded by the anticlinal axis of the S. edge of the town of Tamaqua—axis c. The main street of the town is not far from the next or second synclinal axis, which contains probably about the eighteenth coal, or four or five beds higher in the series than have been preserved at the foot of the Sharp Mountain. The anticlinal between these two troughs lifts apparently about the tenth or eleventh coal to the water-level of the stream, where the arch is visible. There are some indications of an anticlinal, or a disturbance at least of the regular S. dip, between the S. anticlinal of the town and the synclinal at the foot of the Sharp Mountain; and this, if proved, would alter somewhat our estimate of the number of coals lifted on the axis at the stream. It is obvious, on any view, that the synclinal of the central street of Tamaqua must hold coals which are among the highest in the district, as our Section at Tamaqua will show.

North of the synclinal axis of the main street are two others, visible on the road on the E. side of the Little Schuylkill. The first of these passes about 700 feet N. of the road leading towards Mauch Chunk, and the other is 900 feet N. from this one. In the most Northern of these troughs, the fourth in order, the Coal-measures embraced are about as high in the series as those of the second, or that of the main street of the town, there being about seventeen seams visible between the synclinal axis and the conglomerate in Locust Mountain, underlying all the known Coal-measures, counting two pairs of double beds as single ones. Between the second and this fourth synclinal, the Coal-measures undulating over the second and third anticlinals, and in the third synclinal, belong to about one and the same place in the formation, the coals which they include being about the fourteenth and fifteenth of our enumeration from the bottom. The three anticlinals all lift the lower Red-Ash coals to the surface, and may be regarded as constituting a central undulated belt, having a synclinal belt or trough on each side of it, one at the foot of the Sharp Mountain, the other at the base of the Locust Ridge.

It is obvious that the Lower or White-Ash coals, which outcrop in the confronting sides of these two mountain-ridges, undulate in basining under the whole valley, in conformity with these superficial central flexures; but, for the reasons elsewhere explained, I do not think it probable that they undulate as abruptly, or in folds as much compressed, as do the upper, less constrained, and more flexible strata. In viewing all such sections, it is important to keep in mind this probable absence of parallelism in the curves of the outer and the inner or deeper-seated beds, involved in compressed and corrugated synclinal zones like this of the Pottsville Basin.

I proceed to trace, under a new head, these Tamaqua anticlinals, and their basins, Westward to Tuscarora, but shall first present here a subordinate chapter on the details of the coal-seams themselves, as they have been developed in the mines at Tamaqua.

The estate of the Little Schuylkill Company extends Eastward from the river along the N. half of the coal-field for nearly 2 miles, and embraces the whole basin Westward from the river to a line W. of Bucksville. This corporation, after developing its coal-field by tunneling the strata and constructing branch railways, leases its mines to competent contractors, and looks for profit to the large rental to which it is entitled from its very valuable coal-beds. At an early day in the history of its operations, before these coals, outcropping on the opposite sides of the general basin, were identified, every outcrop was named as if it pertained to a separate and independent vein or deposit, and they were designated by the letters of the alphabet, commencing with the lowest then known in the Locust Mountain, and proceeding regularly Southward, irrespective of repetitions by flexure. Thus it happens that the Coals A, B, C, D, D cross-cut, E and F of the N. side of the basin are the equivalents of the Coals T, S, R, QQ, Q, and O of the S. side, or Sharp Mountain. Above these the Red-Ash coals of the two outcrops have not been satisfactorily identified.

Individual Coal-seams.—Immediately below each seam of coal there usually lies the common sandy shale of the Anthracite measures, but the almost invariable covering of the coal is a sandstone. In only one instance does a shale fill up the entire space between two adjacent beds, and this is between QQ and Q in the Sharp Mountain, and their equivalents in the Locust Mountain, D, and D cross-cut. In the one case the dividing shale is 6 feet thick, in the other it is 12 feet.

COALS ON THE NORTH SIDE OF THE BASIN AT THE FOOT OF LOCUST MOUNTAIN.

Coal A.—The bottom rock of this bed is a heavy Nut-conglomerate. The vein has a breast of 700 feet. At the river the dip is about 65° S. The whole coal-bed is about 16 feet thick at the river. It is not worked to the E., and we were informed that it never has been in that direction. The gangway is in, about 1500 feet to the W., and the coal seems to be all in one body, or to contain no parting slate, but it is a good deal fissured and rubbed. Outcrops of three veins have been found north of Coal A, but of these nothing is critically known. Between Coal A and the next seam, B, the horizontal distance on the N. side of the coal-field is 260 feet, and on the S. side, where the dip is steeper, it is 202 feet, filled chiefly with silicious conglomerate.

Coal B.—Is not opened on the E. side of Tamaqua Gap. On the W. side it dips about 65° S., judging by the rocks. The average thickness near the river is about 9 feet. On the mountain it is more than 12½ feet. It crops out N. of the first ledge of conglomerate, about half-way up the N. slope of Locust Mountain.

Coal C.—Was in 1853 worked by a drift on the E. side of the stream; it was driven in 150 yards. It was faulty on the E. side, and was not more than 6 or 7 feet thick. On the W. side it had been driven about 900 feet, and was 8 or 9 feet thick, thickening as it went Westward. The dip at the river is from 55° to 58° S.

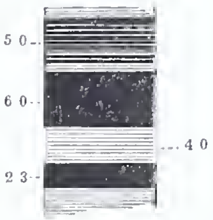


Fig. 143.—Coal C of Tamaqua.

Coal D.—This is the Big Slope Vein of Eaton and Carter, on the E. side of river. Its thickness on the W. side exceeds 14 feet; on the E. it is 12 feet. The gangways from the foot of the slope were, in 1853, driven 600 feet E., and the same distance W. An old upper-level gangway had been driven E. 1400 yards to a rock-fault, which heaved the vein off to the S.E. This vein on the W. side had been driven through to Reinhardt's Run on the top level. The coal was pretty much the same on the top level as it is on the E. side, both in quality and thickness, but it flattens in its dip, which, at Reinhardt's Run, is only 42°. The height of the breast is 280 feet from the upper coal, but in the hill it is 420 feet.

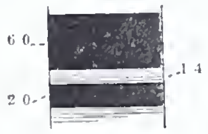
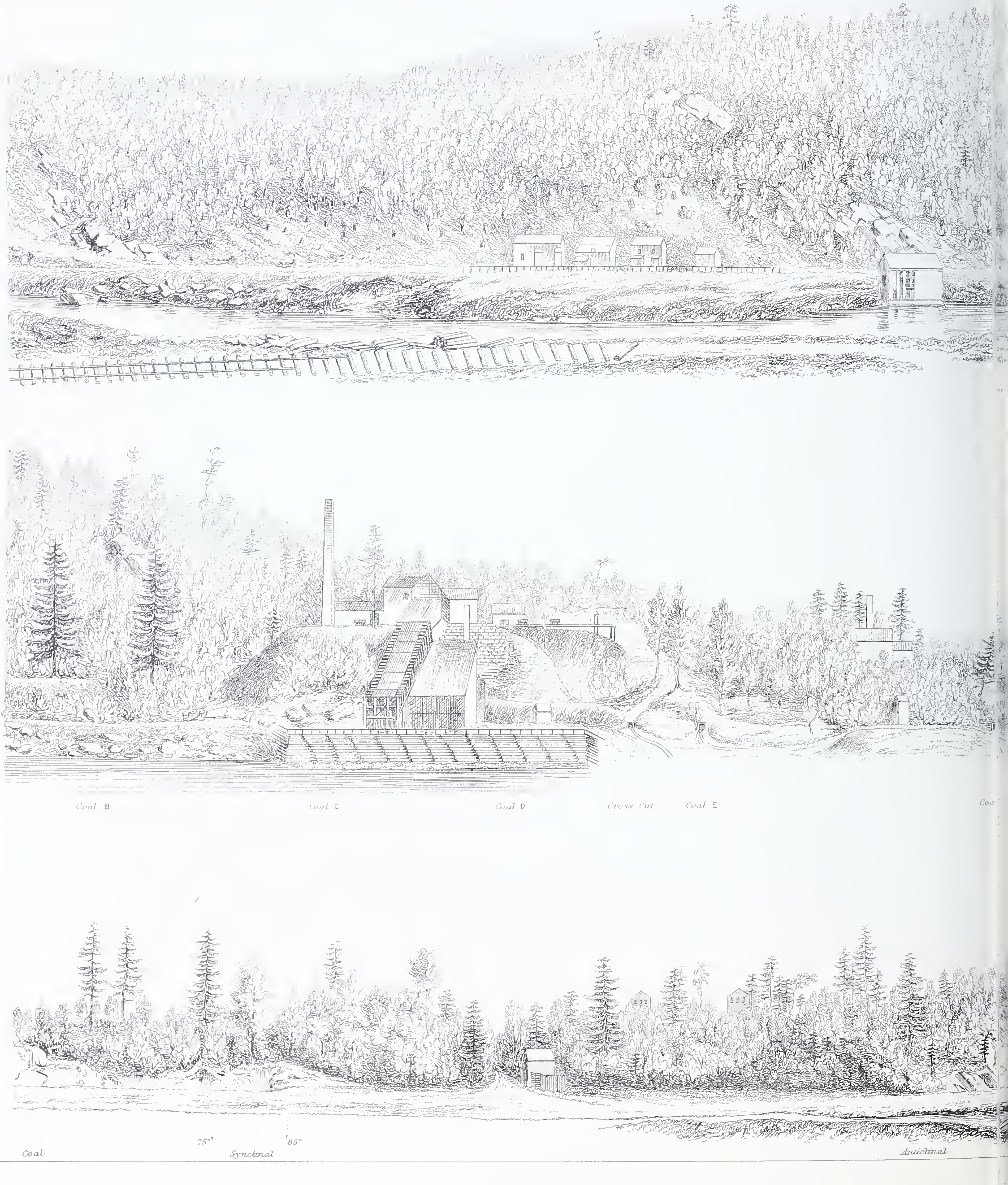


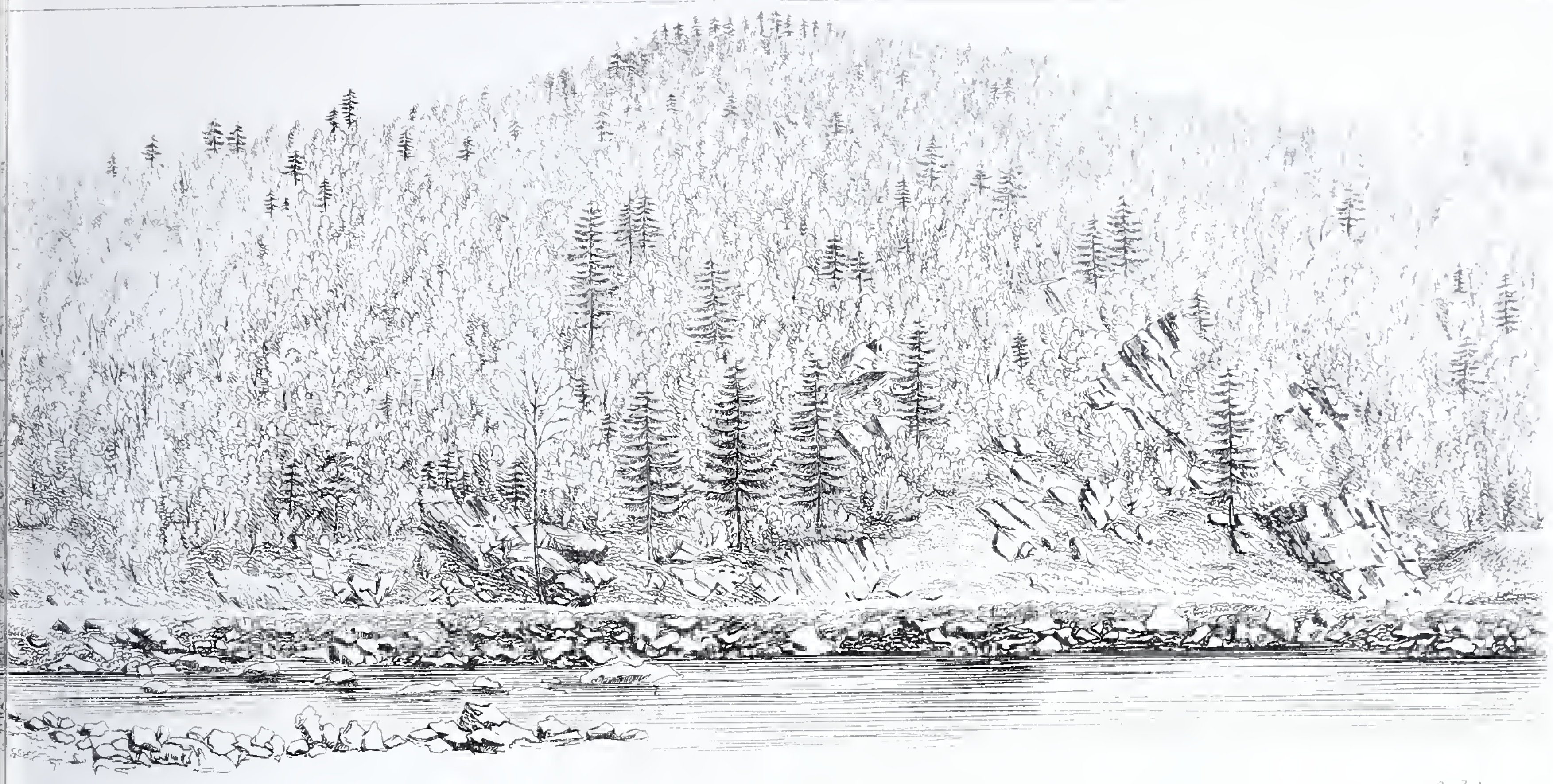
Fig. 144.—Coal D of Tamaqua.

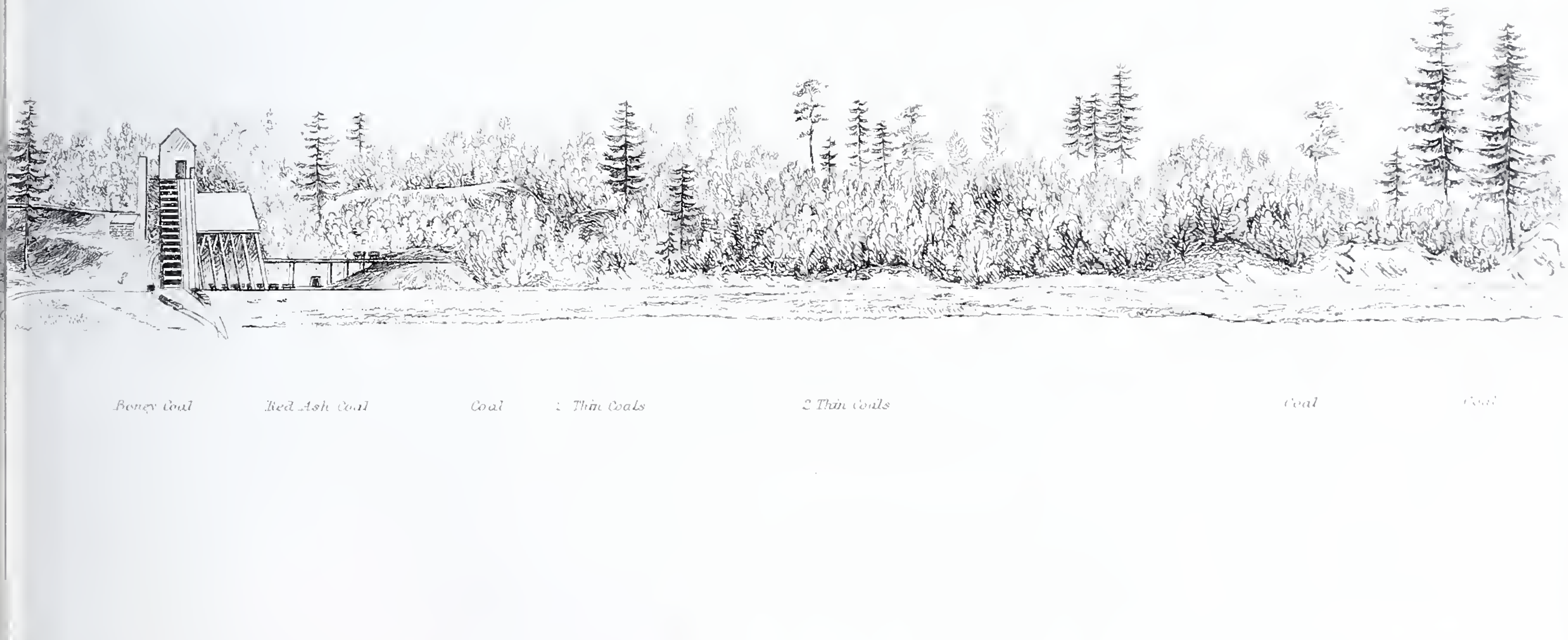
The Cross-Cut Coal.—This bed is only 12 feet N. of Coal E, but at Reinhardt's Run it is 45 feet. It is supposed by some to be the principal vein at Bucksville. At Reinhardt's Run it is 2½ feet thick. At Greenwood Tunnel it is 10 feet thick, but its more permanent average size is 4 or 5 feet.

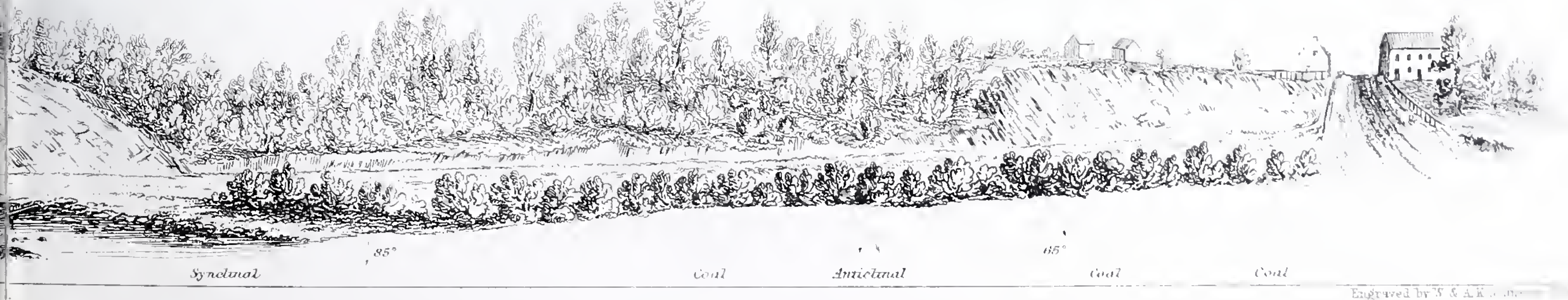
Coal E.—This has been opened on each side of the river. The portion called E East measures between the roof and floor about 23 or 24 feet, of which about 12 feet are very good coal, and the residue is Bony coal and slate. This coal is harder than that of D, but from the larger proportion of inferior coal in the bed, it demands more attention in the preparation for market. E West is a softer coal than E East, the whole bed lying looser between its confining strata. It is hence somewhat more dirty. It has been wrought with great facility, but in a manner not unattended with danger, in consequence of the somewhat loose state of the bed, or want of close compression between the roof and floor. It is wrought in successive levels. At distances of 150 feet along the horizontal gangways, schutes are carried up from one gangway to the next higher, leaving massive pillars of untouched coal between, the roof and coal in the

Pictorial Section, East Side of Little Schuylkill, and North Side of Coal Basin, Tamaqua.









Engraved by W. & A.K. [illegible]

breast above being supported in the usual manner by pillars of wood transverse to the bed, and by a strong floor of plank to hold up the coal. Such is the shattered condition of the whole mass in some parts of the mine, that as fast as the miner picks away the coal next the bottom-slate, other coal from above presses into its place; thus assisted by the freedom of the coal, the workmen in two adjacent schutes can sometimes empty all the coal from the space between them. This fragmentary condition of the coal extends to the outcrop, for in one place at the surface, an enormous hole was at one time formed, 60 feet and more in length, and at least 40 in breadth, by the mere sinking-in of the loose coal as it was withdrawn below within the mine. The dip of this bed is about 54°, that of the opposite portion, E East, is 53°. Between the small intermediate coal-bed (D Cross-cut), and the bed E, the distance at right angles to the dip is about 53 feet.

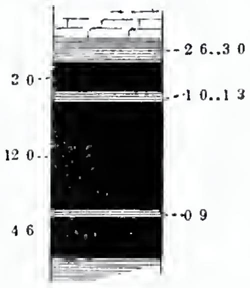


Fig. 145.—Coal E of Tamaqua.

On the W. side of the Little Schuylkill this thick coal-bed is mined through towards Reinhardt's Run, and towards the end of the year 1853 had reached Newkirk Tunnel. It usually contains three benches, but on the E. side it sometimes has four or five. Towards the W. this seam runs rather faulty, but E. it has been worked through to Greenwood Tunnel. Its average thickness is 22 feet.

Coal F.—The next vein, called F, formerly wrought only on the W. side of the stream, is now opened on both sides. At the level of the railroad the bed is in a somewhat crushed condition, and therefore the workings at this lower level have been for some years abandoned. This coal is in two benches. The bottom bench is the thickest on the E. side of the river, being from 6 to 7 feet. On the W. side it is 5 feet thick. The top bench is on the E. side from 7 to 8 feet thick, and on the W. side 6 feet. The lower bench is a pink-ash coal. The dip of this seam averages 60°. Its horizontal distance from Coal E is 270 feet.

The Bony Coal.—This is 138 feet S. of Coal F, at Tamaqua; it is there 6 feet thick.

Red-Ash Vein.—This bed, in horizontal distance, is 100 feet S. of the Bony Coal; it is 3 feet thick.

Coal J, or Jock Vein.—At a distance of 120 feet S. of the so-called Red-Ash Vein occurs the coal-seam J, measuring at its outcrop, which is somewhat faulty, between 6 and 7 feet.

First Twin Coals.—S. of coal J, 48 feet, are two thin beds, 15 feet asunder; they have never been fully opened.

Second Twin Coals.—Distant from the last pair of thin seams is another pair, also about 15 feet asunder. These likewise have never been mined, for they expose too low a breast above the water-level, and they are too thin and worthless to justify mining by pit or slope. Their dip, and that of the strata adjoining them, is 75°.

Upper Red-Ash Coals.—At a distance of 217 feet S. of the Second Twin Coals, we meet the first of a group of three nearly perpendicular seams, which, being near the synclinal turn of the basin, may be called, for distinction's sake, the Upper Red-Ash Group, a term warranted by the great thickness of barren strata which separates them from the group beneath. The *first* of these is about 4 feet thick, though it has never been mined far enough to prove its permanent dimensions. The *second*, 116 feet S. of the first, and divided from it by a rather coarse sandstone, is 3 feet thick. Both of these coals are somewhat crushed or "dirty," a condition which belongs indeed more or less to all the Red-Ash series of the central belt of this part of the basin. The *third* Upper Red-

Ash coal is still thinner, but dipping at an angle of 80° S.: it is very probably in a squeezed state.

Synclinal Axis of Basin B.—The exposures, natural and artificial, on the E. side of the Little Schuylkill, reveal very distinctly the sharp synclinal fold or axis of the N. basin. It shows the strata—slate and argillaceous sandstone—closely compressed into a sharp **V**, the point or axis of which is 240 feet S. of the last-mentioned uppermost Red-Ash coal.

The three thin Upper Red-Ash coals appear to repeat themselves on the S. side of the synclinal axis, at distances somewhat less than those which separate them on the N.; they dip almost perpendicularly, and appear to be very thin—all three circumstances implying that they are squeezed and faulty from proximity to the very sharp and compressed Anticlinal B, which bounds their basin.

Anticlinal B.—The distance of this axis from the centre of the synclinal basin N. of it is 544 feet.

A thin coal, probably one of the Second Twin seams, occurs close to the axis, dipping both ways, and it reappears on the two corresponding sides of the next anticlinal, B, but at a wider distance from that axis. It should be observed, however, that the identification of these thin, faulty, and imperfectly-opened coal-beds is attended with much uncertainty.

Anticlinal Axis B.—This central axis of the coal-field at Tamaqua, already described as crossing the Little Schuylkill just N. of the town, is distant from the first, B, 567 feet, and the synclinal axis between them, belonging to the very closely-compressed basin *B b*, ranges S. of axis B about 305 feet. This anticlinal B, lifting very nearly the same rocks to the surface as the saddle N. of it, is even more compressed, its N. dips being 85°, while its S. ones are as steep as 65°. Two coal-beds appear on the S. flank of this saddle just N. of Tamaqua. The lower one is apparently between 5 and 6 feet thick; the upper one, distant from it about 105 feet, is only 15 inches.

A deep excavation of the coal-rocks, filled up to a level plain by diluvial matter, conceals the native rock under the town of Tamaqua, through a breadth of about 600 feet; but just S. of the village, rock-exposures occur again just at the anticlinal axis C at the E. foot of the hill upon which the S. skirt of the village rests. This anticlinal is distant from the middle axis B 891 feet. The synclinal axis *C b* is probably about 400 feet N. of the S. saddle, and directly under the town.

From the S. anticlinal C to the first distinctly-opened coal-seam of the basin *B* of the valley at the foot of Sharp Mountain is a wide space of 740 feet, within which the strata are very imperfectly recognisable. This interval is apparently occupied by South-dipping Coal-measures, containing doubtless two or three of the lower Red-Ash coals. To the S. of the blank space a succession of very steeply-dipping coals is met with: the first three of these dip at angles from 65°—80° S. These are all crushed, and their true thicknesses, therefore, are not determinable. Beyond the third of these South-dipping beds, we come, at an interval of 70 feet, to a perpendicular seam, called K by the proprietors. This probably pertains to the Sharp Mountain series, or, in other words, seems to belong to the S. side of the basin *D*.

Synclinal Axis of Basin D.—It has been impossible to determine with precision the position of the synclinal axis of basin *D* at the foot of the Sharp Mountain, but my impression is, that it lies either immediately N. of the coal-bed K, or of the coal next N. of it. Assuming it to have the latter position, its distance S. of the anticlinal axis C is about 865 feet. Whatever be its exact place, it is an extremely close fold of the strata; and there can be little prospect of continuously sound workable coal in the three or four lower Red-Ash beds immediately involved in it near the surface. Upon the supposition I have made, the total number of separate coal-seams S. of the synclinal axis, or belonging to the S. outcrop of basin *D*, including the two conglomerate coals underneath coal A, or its equivalent, is just fifteen. This number is less by two than the South-dipping series of the Locust Mountain side of the coal-field N. of the synclinal axis *B*—a difference to be anticipated from the obvious fact, that the anticlinal C—that of Mine Hill—is a stronger wave, with greater vertical uplift than the saddle B, which belongs to the feebler undulation of the Summit Hill.

From the coal-seam K, Southward to the lowest bed opened in Sharp Mountain, we cross a succession of well-proved Red, Grey, and White-Ash coals, the exact equivalents of the South-dipping beds in and S. of Locust Mountain. Comparing the Grey and White-Ash seams of the two sides of the valley, the coal M, 5 feet thick at the foot of Sharp Mountain, is the equivalent of coal J; and N, the opposite outcrop of the so-called Red-Ash bed; coal o, 7 feet thick, the representative of the Bony seam; coal O, 10 feet thick, that of F, also 10 feet thick; coal P, 22 feet thick, of E, which is also 22 feet; Q, 8 or 9 feet thick, that of the Cross-cut coal, 4 or 5 feet thick; Q Q, 8 feet, but variable, of D, which is 15 feet thick; coal R, 9 feet thick, of C, 7 or 8 feet thick; coal S, 7 feet, the counterpart of coal B; and coal T, the equivalent of coal A.

Coal K.—this seam is much crushed and faulty, and has never been profitable. It yields between 4 and 5 feet of bruised Red-Ash coal. Its dip is a little to the S. of the perpendicular.

Coal L is a small and much-crushed seam, which has never been wrought.

Coal M.—This vein is also much disturbed, there having been obviously an extensive movement in the plane of the coal-bed itself, for in some places it is pinched to the dimensions of 3 feet, and then it expands to even 9 feet, and thus throughout all the extent to which it has been wrought. It has a very nearly perpendicular dip. Its distance from coal K is 159 feet. It has furnished some very good coal, but has never, in the main, been a profitable mine.

Coal N is distant from M, the last mentioned, 112 feet. It also is a much disturbed stratum, yielding but little good coal. Its dimensions are about 2½ feet. The dip, always very steep, is irregular, showing a movement in the plane of the bed.

Coal O o.—This coal we could not enter at the time of our explorations, in consequence of the dangerous and obstructed condition of the gangway. It was reported to us as 9 feet thick, but the coal was bruised, and of little value. At the mouth of the drift the dip is a little to the N. of the perpendicular. It lies S. of coal N about 150 feet.

Coal O.—About 50 feet S. of the last named lies the seam called O. At the mouth of the drift the dip of the bed is somewhat irregular, but steep; farther into the hill Westward its slope is 53° N. Like all the Sharp Mountain beds, this coal has experienced a sliding movement in the plane of the dip; and the coal is therefore more or less crushed and fragmentary, although it has really afforded a sufficient proportion of marketable coal to defray the cost of mining. It is alleged to be 10 feet thick.

These previously-enumerated coals of the Sharp Mountain series all yield a reddish ash, that of the last enumerated being the palest. With the next seam commences the White-Ash group of the Sharp Mountain coals.

Coal P.—This is the S. outcrop of the great bed of the basin. For several hundred feet in from the mouth of the drift its prevailing size was 22 feet, but it is stated to have expanded in one locality in the mine to 42 feet. At its outcrop on the mountain-side it measures about 23 feet.

Perhaps not more than one half of the coal in the bed is adapted to the market, the rest being of the earthy sort called Bone coal. It position is about 193 feet S. of the last described, and its dip is from 75° to 80° N. It is now mined below the water-level on the W. side of the river, by a shaft sunk to meet it at a moderate depth below its water-level outcrop.

Coal Q.—Distant about 75 feet from the large bed P lies another coal, called Q, the average thickness of which is 6 feet 6 inches. This is considered to be the best coal in Tamaqua. Its dip, the same as that of P, is 75°. This bed was wrought in the usual mode from the lower levels upwards by schutes. In one spot, after being mined towards the outcrop a distance of 300 feet, the greater looseness of the coal in the higher portions caused it suddenly to rush in from the top, costing the lives of three miners. In the enormous movements which all the Sharp Mountain strata have undergone, when they were elevated from their original horizontal posture into their present nearly vertical dips, they evidently underwent an enormous unequal pressure, squeezing them greatly in certain portions, but loosening and displacing them in others where the cohesion was feeblest.

The several coal-seams and their slates being the least coherent and most easily crushed members of the ponderous body of strata, any sliding of the mass during upheaval was necessarily greatest within the materials of these softer layers, and in the plane of their slope. Hence the fragmentary condition of so much of the coal in the Sharp Mountain, the elevation of which seems to have been attended, even in the district of the Little Schuylkill, with the production of an enormous compression of the rocks near its N. base. These views should be daily in the thoughts of those who are working the Sharp Mountain coals, for as the mining operations there advance, the danger to life and property must inevitably increase.

Coal Q Q.—At the level of the railroad the space between this seam and Q, the last described, is not more than about 7 feet, but at a counter-level 220 feet higher they are separated by 12½ feet of slate. They are both entered by one external drift. The bed Q Q measures between the bottom and top slates about 7 feet, and it turns out 4 feet of good coal, except in those places where it is crushed.

Coal R.—This seam, which is stated to have a thickness of 9 feet, lies S. of Q Q 205 feet. It was originally entered by a drift at the level of the railroad; but the workings on this level were arrested by an oblique fault bringing against the end of the drift a mass of slate dipping towards the W. It has been since penetrated in another more successful drift, at an elevation of nearly 300 feet above the former. Some of the coal of this bed is very beautiful.

Coal S.—The workings upon this vein were at the period of our investigations so dilapidated as to preclude the determination of its dimensions, but it is stated to be 7 feet thick. It is obviously not a sound nor valuable seam. Some of the coal appeared to be of a good quality, but the bed is too soft and shattered to prove profitable. Its distance from the main upper layer of the Seral conglomerate, which forms the crest or backbone of the Sharp Mountain, is about 202 feet, and its dip is about 70° to the N.

The total thickness of the productive Coal-measures at the Little Schuylkill, counting from the synclinal axis *B* to the bottom of coal A, is apparently about 2000 feet. As basin *B* is probably the deepest of the four caused by the three anticlinals, it is obvious that 2000 feet is the maximum depth at which coal A can lie anywhere beneath the surface of the valley. A shaft or a deep subterranean tunnel of that length will therefore cut all the fifteen coal-seams to A inclusive, and one about 1300 feet long should reach the thick and valuable coal E. Of course, shallower pits and shorter tunnels will penetrate to the same coal-beds in the basins *B b*, *C b*, and *D*, and still less extensive ones on the anticlinal axes B, ʙ, and C, though the anticlinals are seldom the most suitable belts in which to sink deep shafts. Probably the most economical mode of reaching a large amount of sound coal beneath the water-level will be found to be, for a long time to come, by slope-pits sunk in coals E or D, and by a tunnel driven N. and S. from the bottom of the slope. Indeed, this process is employed, in the present time, at relatively superficial levels. Our panorama sketch of the collieries exhibits the exterior arrangements connected with a slope-mine in coal D. Ultimately it may be found desirable to sink one or more perpendicular shafts near the middle of the coal-field, and then, more probably, basin *B b* or *C b* will be chosen as admitting of the most entire command of the deeper-buried wealth of the region.

GREENWOOD TUNNEL.

At the first tributary of Panther Creek, E. of the Little Schuylkill and about a mile from Tamaqua, the South-dipping strata on the N. side of the Locust Mountain basin, or that bounded on the S. by the Summit Hill anticlinal, are penetrated Northward by an extensive tunnel, the opening of the Greenwood Mines. This tunnel has its mouth in the Red-Ash Coal-measures, about 300 feet N. of the synclinal axis of the Locust Mountain basin. A little more than half-way in, it cuts the lower Red-Ash coal F, and then E, the Cross-cut, and D in succession, terminating, at the time we saw it, in the latter. The rocks at the mouth of the tunnel—grey pebbly sandstones—dip 45° S. 20° E. The immediate entrance is in slate. (For Section of Tunnel, see woodcut, fig. 146.)

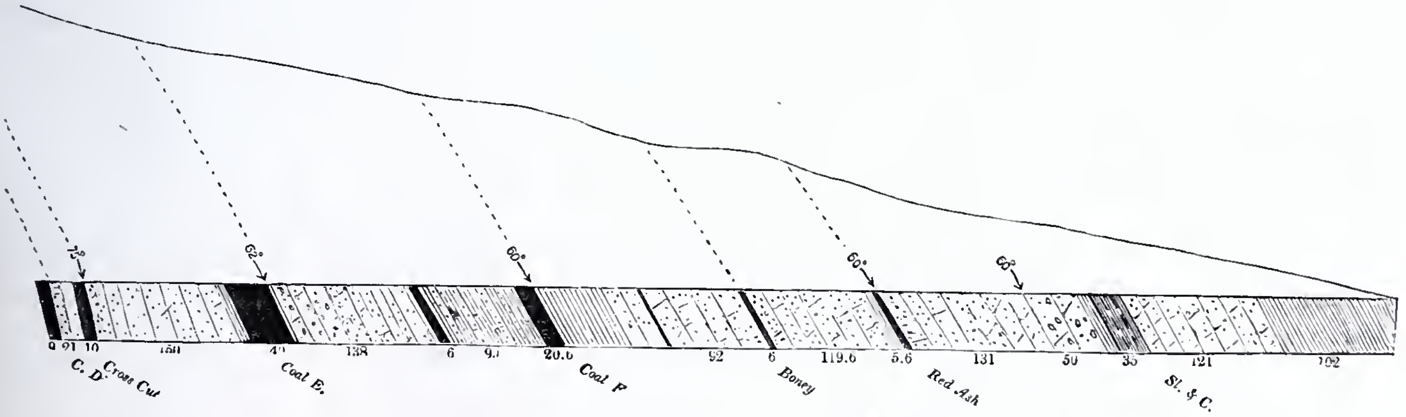


FIG. 146.—Greenwood Tunnel, in Locust Mountain.

The first coal cut in the tunnel is the small Red-Ash bed S. of the Bony coal, and then the Bony coal. The vein F has been mined Eastward about a mile and a half in the tunnel-level. A slope-mine enters it at Carter's New Slope, 3000 feet E. of Greenwood Tunnel. The bed is there from 12 to 15 feet thick, and dips 50° S. Its ash is pinkish grey and white.

CHAPTER IV.

THE SCHUYLKILL OR CENTRAL DISTRICT OF THE COAL-FIELD.

INTRODUCTORY DESCRIPTION.

Before proceeding further to describe in detail the structure and contents of the coal-field, it is expedient to present a geographical sketch of the great Middle Division of the Southern basin, or that which is drained by the waters of the Schuylkill, and which has Pottsville for its centre. This extends to Tuscarora on the E., and to the sources of the West Branch, Schaffer's Run, and Muddy Branch on the W. It embraces the widest portion of the basin—that in which we find the greatest amount of irregularity in the position of the strata, and where the largest number of active collieries are assembled. It is therefore the most intricate and important of all the mining districts within the anthracite region. It will be seen, on inspecting the Map, that this district, drained by the waters of the Schuylkill, constitutes a very natural subdivision of the basin. The rising of Mine Hill, near Tuscarora, almost into the centre of the valley, and the abrupt change of position to the S. of the Sharp Mountain near Middleport, cause it to be partially insulated from the Eastern narrower end, while on the W. the throwing forward to the S. of the flank of the Broad Mountain beyond the West-West Branch, seems, though in a less marked degree, to divide it from the district watered by the sources of the Swatara.

In its topographical structure this part of the basin is admirably adapted for the extensive and easy development of its mineral breadth. The whole interior of the valley is traversed longitudinally by nearly parallel ridges and intervening depressions, produced by the combined agency of anticlinal folding of the strata, and the carving of the surface by denuding waters. These undulations amount to a difference of level of from 100 to nearly 400 feet. But there is a still more important feature favourable to the extraction of the coal: the entire district is intersected *transversely* by the tributary valleys of the Schuylkill, and by their subordinate ravines. The wild floods, which originally breached the notches in the mountains for the passage of the present rivers, in sweeping S. across this district, have formed a series of deep cross valleys, the chief of which traverse the whole breadth of the basin, while the minor ones penetrate from the S. side only to the middle and N. border of the valley. These great natural trenches, by intersecting the longitudinal ridges, give ready access to a multitude of coal-seams, which are entered endwise at various depths below their upper outcrops, so that extensive slopes or breasts of the coal are procurable above the water-levels, and therefore without the expense of mine-drainage by machinery. They are, furthermore, the natural excavations approximately graded for the reception of the numerous lateral or branch railroads by which the coal is conveyed from the mines into the great channel of trade from the district, the valley of the Main Schuylkill.

The most conspicuous of these transverse valleys are those of Mill Creek, the West Branch, and the West-West Branch. These enter the basin from the Broad Mountain, breach the axis of Mine Hill, and traverse the valley to the very base of the Sharp Mountain. The Eastern Branch of the Schuylkill, from Tuscarora westward to Pottsville, along the S. border of the basin at the foot of the Sharp Mountain, is the main trunk of an extensive series of such subordinate transverse ravines, which, commencing in the N. side of the field at the base of Mine Hill, and the lesser ones in the middle of the valley, open Southward into it as their natural outlet. Advancing W. from Tuscarora, the first of the more conspicuous of these cross ravines is that of Big Creek, which stream rises in the little valley between the Locust Mountain and Mine Hill, and in passing the subsiding axis of this latter, lays naked an extensive body of Coal-measures. The next is that of Casca William Run, upon which are several collieries.

It opens into the Schuylkill near the little village of Middleport. Further W. are the valleys of Lick Run and Lime Creek, upon both of which are now seated some promising collieries ; and beyond these occur two or three lesser valleys, and then the more extensive one of Zachariah's Run, the locality of several extensive mines. Another considerable ravine opens between this last and Mill Creek, upon which are also extensive collieries.

That important division of the district which is included between Mill Creek and the West Branch is penetrated throughout its entire breadth, from Pottsville to the flank of Mine Hill, by two other large valleys at right angles to the strata, those of East Norwegian and West Norwegian creeks. These unite N. of Pottsville, and the combined stream follows thence a single valley, directly transverse to the strata, to the main defile in the Sharp Mountain, where it joins the Schuylkill.

Nearly every valuable bed of coal intersected by the five principal transverse valleys of Mill Creek, East and West Norwegian, West Branch, and West-West Branch, has been opened, and has been, or is now, the seat of mining operations. Formerly the coal-workings were restricted to the portions above the level of the adjacent valley, but of late years extensive collieries have been established, in which the coal is wrought to already considerable depths below the water-level. Availing ourselves of the data thus supplied by artificial exposures of the strata, and combining with these the measurements of all the recognisable natural outcrops of the beds, we have succeeded in partially unravelling the structure of this excessively complicated district. I cannot pretend to exhibit here an entirely accurate representation of the course of every coal-seam, for in the present still infant state of development of this great coal-field, the materials are not yet discovered for the delineation of its many beds of coal in their intricate windings upon the surface, and their still more perplexing changes of dip and dislocation under ground. No one of the principal ravines crossing the basin supplies by any means all the facts essential for the construction of full general transverse sections of the strata representing the outcrops and the underground flexures of every coal-seam. I have been compelled, therefore, to resort to an extensive and laborious compilation of data gathered along the valleys of the Main Schuylkill and its tributaries, for materials for the several sections of the basin herewith presented.

ANTICLINALS AND BASINS BETWEEN TUSCARORA AND EAST NORWEGIAN.

Anticlinal D, *or Axis of South Mine Hill.*—Regarding the axis S. of Tuscarora as the E. prolongation of this conspicuous and important anticlinal, we may view it as originating in the N. flank of Sharp Mountain, somewhere S.E. of Tuscarora. We first recognise it W. of the valley of the Schuylkill, in the S. side of the hill next W. of that of Tuscarora, where it bounds Chadwick's Basin on the N. It crosses the Pottsville road near its abrupt bend Southward towards the Schuylkill, passes S. of Silliman's Breaker on Big Creek, and is the saddle which heaves and confuses the coal in Whitfield's Lower Tunnel. Passing near or through the tunnel at the head of Bushy Valley, it enters the E. point of the South Mine Hill at Casca William Creek, turning the large White-Ash coal of that locality abruptly into a steep N. or perpendicular dip, immediately at the engine-house of the Slope Mine. Thence it ranges along the N. side of the crest, and in some places near the base of the same to the Western termination of this ridge, S. of Little Wolf Creek, and thus, keeping a remarkably straight course, passes on and appears at Mill Creek in the arch just S. of Johns' Slope, and dies away in a flattening undulation on the flank of the Main Mine Hill, between that valley and the head of the East Norwegian. In some parts of its range between Casca William and Mill creeks, this anticlinal is so sharply folded as to produce a fault or dislocation sometimes at the synclinal turn just N. of it, sometimes in the vertical leg of the arch itself. It is this axis which gives the undulation to the large coal called Guiterman's Bed, on Silver Creek. Throughout the whole of its course from near Tuscarora to Mill Creek, excepting chiefly the vicinity of Silver Creek, where it arches somewhat gently, this axis is characterised by a very steep S. dip, and an almost perpendicular or even slightly overturned dip on its N. side; hence it is that the crest of the narrow ridge which it elevates, and which I propose to call the South Mine Hill, is so remarkably craggy and broken, composed of successive steep standing ribs of the dense and massive conglomerates of the White-Ash Coal-measures, denuded by the violence of the waters scooping the softer interposed rocks, which elsewhere, with gentler dips, would give a softer contour to the scenery.

Coal-Beds lifted by this Axis.—The coal-beds lifted to the water-levels of the streams which intersect this anticlinal, are not identifiable with precision between Tuscarora and Casca William, or as far at least as Whitfield's Lower Tunnel. We can merely say, that those which span it in the vicinity of Tuscarora and Patterson are members of the lower Red-Ash series. Rising to the Westward, the axis gradually, however, lifts out the more deep-seated coals, and at Whitfield's Lower Tunnel brings to the level of that gallery—so the evidence implies—the uppermost of the White-Ash coals, or the Big Coal, so called, of the S. slope of the South Mine Hill, the equivalent, as I regard it, of the coal E of Tamaqua, and of the collieries Eastward and Westward at the S. foot of Locust Mountain, from Upper Panther Creek Valley to Palmer's Tunnel at Tuscarora. At Casca William Creek this coal is brought to the level of the point in the South Mine Hill, at Rogers' and Sinnickson's White-Ash Colliery, W. of which it is divided by the rising and expansion of the anticlinal into two gently-diverging outcrops, the Northern one of which runs W. the chief part of a mile, probably to basin in the synclinal valley enclosed between the spur of South Mine Hill and the S. flank of the Mine Hill proper, and to take its course thence Eastward in the latter through the Casca William Tunnel, and through Whitfield's Upper Tunnel, and Silliman's and Potts' slopes on Big Creek north of Patterson. The E. outcrop, on the other hand, starting at the point of the spur at Casca William, follows the S. slope and base of this ridge the whole way to its termination near Mill Creek, being the so-called Big Seam of Tucker's Slope Mine on Silver Creek, the Big Seam of Zachariah's Run, or of the Windy Harbour Tunnel at Zachariah's Run, and the Mammoth Vein north of Crow Hollow, and of Mill's and Pinkerton's mines on the two sides of Mill Creek. Several lower coal-beds are lifted and exposed on the S. flank of this axis, even a little W. of Casca William Creek, and a greater number still on Silver Creek, and N. of Windy Harbour, as the Sections will show. But approaching Mill Creek, some of these subjacent coals again bury themselves with the Westward slight declension of the axis, until, at Johns' Colliery, the lower Great White-Ash coal, which at Silver Creek bends over the arch at a high level at Guiterman's former workings, does not much more than rise here to the bed of the valley. As this anticlinal encroaches in going Westward more and more upon the base of the Main Mine Hill, it leaves a less and less width and depth in the synclinals N. of it, so that that which at Casca William is a basin of some breadth and capacity, becomes, at Silver Creek and at Mill Creek, a mere rolling over, with more or less of fault, of the prevailing S. dips into a very narrow line of steep N. ones. As is very frequently the case, the flexure becomes more dislocated as it thus contracts in breadth, and degenerates into a more sharply-pinched fold.

Anticlinal E, *or Casca William Diamond and Northern St Clair Axis.* — The next anticlinal which presents itself in order Southward is one of less length and of gentler dips. Our first indications of it to the E. are in the watershed between Bushy and Casca William valleys. No N. dips at the first named of these valleys indicate its existence so far E. This axis passes Casca William Valley about 200 feet to the N. of the Slope Mine on the South Diamond coal, holding the Diamond group above the water-level of the district, from thence to Silver Creek, where the coal called the Big or North Diamond arches the axis, to rise again immediately behind it, and outcrop with its prevailing dip to the S. The line of the saddle crossing Silver Creek passes directly under the Public School-house, and thence through the watershed, dividing Silver Creek from Zachariah's Run, into which valley it descends along a ravine leading down to Windy Harbour. From this point the flexure seems to decline to the Westward, though, by its obliquity of direction as respects the general range of the coal-basin, it causes lower coals instead of higher ones to saddle in succession as it passes. Thus reaching the vicinity of Crow Hollow, it enters the district of the large upper White-Ash coal or Mammoth bed, where this is mined at and below the water-level; and it is the cause of the great and sudden change in the course of the gangways or levels of the mines in that vicinity, which, leaving their Eastward trend, swing Southward to pass round this flexure. Approaching Mill Creek, the anticlinal passes under the swell of hills S. of Milne's Slopes, undulating here the Big Vein in which it crosses the valley, to disturb the gentle Southward dip of the overlying Primrose Seam on the opposite side, or to the W. of St Clair.

Of the Basin C D, or that between the Main Mine Hill and the South Mine Hill.—This basin, lying immediately N. of the axis just described, embraces at Tuscarora, and thence Westward to near Big Creek, as we have seen, two subordinate saddles, or two chains of short interrupted saddles, undulating the lower Red-Ash Coal-measures. But at Big Creek, and from thence Westward, by virtue of the rising of the main axis of East Mine Hill, and the consequent lifting of the general basin, the Red-Ash coals are thrown out, except near the S. side of it, in the vicinity of that stream, and as far perhaps as Whitfield's; and beyond this latter locality to the Casca William Tunnel, it is doubtful if any but the Grey-Ash group are retained in the centre of the trough, while the uppermost coal left in the valley to the Westward of that tunnel is probably the upper Big White-Ash seam. At Silver Creek, not only this seam, but all the underlying beds until we reach the large one called Guiterman's, have been lifted and washed out from the contracted trough ; and at Mill Creek it retains nothing higher than Johns' large bed, the equivalent, as we conceive, of the large seam over Guiterman's of Silver Creek, and there called Chadwick's.

Basin of Anticlinals D *and* E.—To understand the structure and contents of the basin at the S. foot of the S. ridge of Mine Hill from Casca William to Mill Creek, it is only necessary to consult and compare the several Sections which illustrate the region of this group of axes, and to observe that, in consequence of the greatly superior elevation and sharpness of the N. anticlinal D, compared with the S. one E, the two sides of the trough are of very unequal breadth and capacity as respects the coals elevated above the water-levels. The S. or lesser flexure operates, in fact, merely to undulate the upper strata of this basin in their descent towards the South, or to check and turn their prevailing S. dips for a brief space into N. ones. Thus at Casca William Valley, from the anticlinal D to the synclinal turn or axis, we have, in the space of some 1400 feet, all the coals presented in a gradually-declining dip from the large White-Ash seam to the Big or North Diamond; while from the synclinal line to the anticlinal E we have only a space of about 150 feet, and no return of any of these coals to the surface, except the uppermost or North Diamond itself. On Silver Creek we meet with even a greater disparity in the number of the beds presented on the two sides of the synclinal, the Northern, embracing the whole series of coals from the Guiterman bed, low down in the White-Ash measures to the North Diamond of the Red-Ash; whereas the Southern, precisely as at Casca William, re-elevates only the uppermost, which is here the North or Big Diamond. From the Northward trend of the basin, and its entering belts of lower and lower coals, we find it to contain, on Mill Creek, at or near the water-level, only the White-Ash Mammoth seam, and the overlying Grey-Ash Primrose, and its companion beds.

In different parts of this valuable synclinal range, the simplicity of the synclinal structure is interrupted by an occasional anticlinal roll, or short local saddle. One such is encountered just S. of the Casca William White-Ash Slope, and ranges for some distance parallel to the foot of the spur of South Mine Hill; but this undulation seems to smooth itself out before we reach Silver Creek, or even a point opposite the head of the Lick Run Ravine. In the same part of the basin there are indications, from the course of the outcrop of the Diamond coals, of a similar trivial axis South of the preceding. In the vicinity of Mill Creek, a broad gentle saddle of this sort arches the upper White-Ash coal, or the so-called Mammoth Vein, and near that valley even exposes by denudation an arch of the main Nut-conglomerate stratum which supports that coal. The position of this anticlinal is a few hundred feet S. of Johns' Breaker. The highest coal which it elevates is a small seam next under the Mammoth bed. This has been experimentally shafted just under the crown of the flat symmetrical arch. The evidence presented by various trial-shafts sunk on the flank of this ridge goes to indicate that the next subjacent coal-bed, the great White-Ash seam worked by Johns, is at or very near the surface in the line of the anticlinal. How far this saddle ranges to the E. has never been determined; but notwithstanding the exploratory diggings undertaken here by different parties, the coal within this saddle has not been satisfactorily traced, or, if ascertained, has not yet been divulged. That the saddle expires in a length of perhaps half a mile seems probable, from the most careful study which we have been able to give it. This flexure is felt to a less extent on the W. side of the valley of Mill Creek, flattening and extending the breast of Pinkerton's Mammoth Vein between its outcropping and the level of the valley.

Anticlinal F, *the Patterson and St Clair Axis.*—We now come to another and leading anticlinal, extending the whole way from the vicinity of Tuscarora to Mill Creek and East Norwegian. It seems to originate in the shoulder of Sharp Mountain, E. of the depression opposite Beachem's Lower Tunnel, and it ranges thence by the Schuylkill and a little S. of Patterson, where both its N. and its S. dips are easily discoverable. From Patterson we may trace the line of this anticlinal through the De Long tract, and across the Bushy Valley, where it arches the Adam Stahl coal-bed, and again past the valley of Casca William, where it seems to lift to a higher level the same coal-bed. From Casca William we have traced it through Lick Run, where it passes N. of the massive bed of lower conglomerate exposed on the old railroad above the most Northern of the Mine Drifts of that valley. It ranges to Silver Creek through Quigley's Hollow, and, crossing the hill W. of this, appears at the main valley of Silver Creek as the anticlinal which rises on the centre of the double fold of conglomerate cut by Tucker's Switch-back railroad. On the W. side of Silver Creek it is to be detected in the low spur which is next S. of the ridge sustaining the School-house, and, rising and expanding Westward, it comes out on Zachariah's Run just to the N. of the folded synclinal coal-bed of Windy Harbour. Though some obscurity attends the detailed tracing of this axis for some distance further forward, our researches leave but little room to doubt that this is the anticlinal of the N. base of the spur which separates Crow Hollow from Ravensdale, and which is met with in the N. end of Ravensdale Tunnel in the form of an inverted flexure, doubling the Primrose Vein backward under itself. At Mill Creek it is traceable by the saddle which passes a little N. of the line of Carey's Shaft, and which there lifts the Primrose Coal to its shallow position in that shaft, throwing out the Orchard Vein altogether from the low grounds to the N. of the hill. From Patterson to Silver Creek this flexure is of a normal form, or but moderately compressed; but Westward it seems to be more closely folded, the inflexion reaching to a strong reversal of the dip in the Ravensdale Tunnel. Beyond this point it rights itself, and rapidly dilates and subsides, until at Mill Creek and East Norwegian it is but a gentle and symmetrical undulation, scarcely noticeable as a part of a great leading anticlinal.

Coal lifted by Axis F.—Adverting now to the coal-beds which this anticlinal makes accessible at the surface, we may mention that the Adam Stahl Vein, brought out by it on the De Long and Bushy tracts, is in all probability one of the seams of the middle Red-Ash series somewhere above the upper Diamond, but by how many terms separated it is not possible to say. On Silver Creek this axis brings above the water-level of that valley about the fifth coal above the Big or North Diamond inclusive, and, at Zachariah's Run, most probably the second coal below this fifth, or possibly the South Diamond. At Ravensdale and Crow Hollow the coal which saddles the axis is, as we have seen, the Primrose; while on the W. side of Mill Creek, as already shown, it throws out the Orchard, and brings the still subjacent Primrose nearly to the surface.

The D F and E F Basin, or that of Patterson and St Clair.—From Beachem's Mines, in Sharp Mountain, to the Bushy Valley, there is but one basin embraced between the anticlinals F and D, if we except a local subdivision of this to the Eastward, arising from the intrusion of the short saddle D; and the general synclinal line of this comparatively broad field ranges a little to the N. of Patterson, the axis of the trough being visible on the road between Beachem's Lower Tunnel and the village of Brockville. But from Casca William Creek to Mill Creek the introduction of the axis E greatly narrows the basin lying to the N. of our anticlinal F, the average breadth of which nowhere amounts to more than from 800 to 1000 feet. From Patterson, as far Westward as Casca William, the middle Red-Ash coals evidently lie within the synclinal belt, and at Silver Creek we have the fifth above the North Diamond inclusive, the same which spans the axis S. Even as far as Ravensdale and Crow Hollow the Diamond coals are embraced within this basin—at least they bear this name there—and the coals actually belonging to it cannot be far from the Lower Diamond. It is not till we come to Mill Creek that all the Red-Ash coals are lifted out of the now narrow and shallow trough, and that the Grey-Ash seams, the Primrose and Orchard beds only, are left undenuded in its gentle synclinal wave. It is into this basin that the Casca William Red-Ash slope on the South Diamond penetrates, and it is this which contains on Silver Creek the North and South Diamond slopes of Mr Neill. In this basin the Mammoth Vein, held up by the anticlinal E, is entered at Crow Hollow by Silliman's Water-Level Tunnel, and this is the basin of the present lower slope-workings of the Mammoth Vein both E. and W. of Mill Creek. Carey's Shaft penetrates to that vein at a depth of 400 feet, in the basin next to the S. of this, or that which we have called F G, but the anticlinal F being here a very gentle one, no obstacle of importance will be presented to the working of this valuable coal-bed from the one basin into the other.

Subordinate Anticlinals D *and* D D.—The basin on the N. of our anticlinal F contains, as already mentioned, a short saddle, which, from its lying most contiguous to the axis D, is entitled D. This is a sharp or compressed axis, running from the Schuylkill, where it first shows itself about half a mile below Tuscarora, for about one mile to the Westward, crossing the Pottsville Road a few hundred yards to the N.E. of Brockville. It is the saddle to which belongs the perpendicular or slightly-inverted dips at Chadwick's Little Breaker, the anticlinal axis being obviously but a short distance to the S. of this: the N. dips seen on the road N.E. of Brockville are also connected with it.

The *Basin* composed of these N. dips of the saddle, and the gentler, though still steep ones of the anticlinal D north of it, is that in which Chadwick has recently opened a small colliery in one of the Red-Ash veins, basining at the centre under the water-level; but of what precise coal of the series this is the equivalent, the imperfect developments of the coal-field preclude us from ascertaining.

Saddle D D.—There is, in the N. part of the Bushy Valley, a small saddle about the middle of the synclinal belt *D F*, on the parallel of the lower Red-Ash coals, which, for facility of reference, we may call D D. It has not been traced any distance either E. or W. of the valley, and we only know that it is an important local disturbance of the Coal-measures.

Axis G—Anticlinal of the Silver Creek Switch-back Railroad and of South St Clair.—This is an anticlinal axis holding a distance of from 800 to 1000 feet S. of the long axis F, which it does not, however, seem to accompany much further Eastward than Silver Creek or Lick Run. It is possible that it may cross Lick Run, though the exposures and developments are there too obscure to enable us to decide positively respecting its existence. The magnitude of this flexure on Silver Creek would seem to imply that it is there already a considerable distance from its commencement. It crosses Silver Creek S. of Quigley Hollow, and a little N. of the great bend of the Silver Creek Switch-back Railroad, and on the W. side passes just N. of the Slope Colliery of the Diamond or Gin Vein. It crosses Zachariah's Run through the deep ravine which separates the two synclinals of coal, and, traversing the watershed between this valley and that of Ravensdale, where it lifts the Little Perpendicular Vein, so-called, it passes across Crow Hollow, and so on to Mill Creek, where it folds the Hancock Vein northward over upon itself, and supports the Big Diamond coal upon its S. dip.

In the district of Silver Creek this is a normal flexure, steep on its N. side. But it becomes an inverted or folded one as it advances Westward as far at least as Mill Creek. On Zachariah's Run and Ravensdale we see it connected with perpendicular N. dips, and at Mill Creek, as already intimated, it folds back the Hancock Coal far over upon itself.

The coals elevated to the water-level of the first valleys intersected by this axis are considerably lower in the series than those brought up by the neighbouring anticlinal F. They are the same, indeed, on Silver Creek as are lifted out by the axis E—in other words, the Lower Diamond Veins. And this is very nearly the relation of things on Zachariah's Run. From the structure visible on Mill Creek, as exemplified in our section, where we make the Orchard Coal identical with the Hancock and the Lower Diamond, this axis lifts very nearly the same Coal-measures, which are there elevated by the adjoining axis F, and not by the remote one E, which has nearly subsided.

Basin F G.—From the superior force of the anticlinal G compared with F, in their range from Silver Creek to Mill Creek, the basin embraced between these axes presents a feature the reverse of the trough E F, and the wider one D E. In the present instance, the synclinal line is much nearer the N. axis than the S. one; and as a consequence, the N. dips from the anticlinal G greatly preponderate over the S. ones connected with the axis F. Hence it is that on Silver Creek there are five nearly perpendicularly-dipping coal-beds on the S. side of this trough, opposed by only a single South-dipping bed, the uppermost of course, of these five, on the N. side; and such is very nearly the condition of things on Zachariah's Run. We have already intimated that on Mill Creek, where this is a folded synclinal, the Hancock or Big Diamond, which is an inverted seam, is that which is involved in the fold.

Anticlinal H—*that of Sillimanville and Mill Creek Furnace.*—This is an important anticlinal, extending the entire distance from Sillimanville to the East Norwegian, and even further and is interesting as being the axis which limits on the N. the greatly prolonged and remarkably folded synclinal belt of the Peach Mountain coal-vein. From its apparent origin, a little W. of Sillimanville to Silver Creek, the line of the axis is very slightly concave Southward; but from that stream W. it is remarkably straight. This anticlinal is first plainly recognised E. of Bushy Valley in Bennett's Upper Peach-Mountain Vein, where an air-hole has been pierced from the mine to the surface, immediately on the axis. It is the saddle of the hill immediately N. of the junction of Bushy with Casca William valleys, and the hill N. of the Old Valley Furnace on Silver Creek, the crest of which it follows over to Zachariah's Run, where the arch-like character of the flexure is well exhibited at the cutting of the Old Drift Road south of the Gin and Perpendicular veins, a conglomeritic sandstone there spanning the axis in a symmetrical saddle. It is equally well exhibited on Silver Creek; but the dense small vein of conglomerate there seen in it is higher than that of the axis on Zachariah's Run by several coal-beds. We meet with it on Ravensdale, in a bold hill S. of the mine there wrought in the folded synclinal of that valley. Maintaining its course in the same belt of hills, it ranges across Crow Hollow under similar features and relations to the steep strata immediately N. of it, passing through the watershed which separates that valley from Mill Creek. From Crow Hollow to the East Norwegian it everywhere holds its station in the S. summit of the double-topped broad hill visible on both sides of Mill Creek, where it is the axis to which belong the steep N. dips of the so-called Perpendicular Vein, a little N. of Patterson's Furnace. This anticlinal is remarkable, throughout its whole course until we reach East Norwegian Valley, for the great steepness, even to perpendicular, of the dips on its N. side, and for the relative gentleness of the dips upon its S. Even to the E. of Bushy Valley, the quarter of its assumed place of origin, the N. side of the wave is almost perpendicular; and not till we reach East Norwegian, where it begins to subside, does it assume the gentler form of a symmetrical saddle. At M^cGinnes's Shaft and Boring, sunk abortively on this axis in the vain expectation of finding the large Mammoth White-Ash coal of the Mine Hill approaching the surface within an accessible distance, the N. and S. dips are both about 48° or 50°. In this closely-compressed character of the flexure towards its E. end, and its subsidence W., we find it to agree with all the anticlinals to the N. of it, where they are traced to their terminations; and we are forcibly impressed with the conviction that they all owe the feature to one condition attending their formation—viz., to the remarkable thrusting forward to the N. of the part of the general coal-basin to the E. of Middleport, or what is an equivalent view, to the closer compression in that quarter of the general synclinal trough of the coal-field from the intrusion from the E. of two large anticlinal waves from the country outside of the valley. The Section will give the names of the coals at this axis on Bushy, Casca William, Silver Creek, Zachariah's Run, Ravensdale, Mill Creek, &c.

Coals lifted by Axis H.—Adverting to the particular Coal-measures which are elevated successively along the line of this extensive anticlinal, we find that they are very nearly the same for the whole distance from Bushy Valley to that of East Norwegian. In general terms, the coals which it produces at the water-level of the valleys, which successively intersect it, are usually in position five or six seams under the Main Peach Mountain bed, or those that appertain to the middle Red-Ash group. It is true, they bear various local designations in the various valleys where they have been mined, but it is one of the fruits of the patient researches connected with this Survey, that we have made their general identity clear. The exact relationships of the coal-beds brought up by this anticlinal at its intersection by the different valleys will be readily gathered from a comparison of the cross sections of the basin, and of the table of synonyms of the different coal-seams.

Basin H F and H G.—From near the Schuylkill Valley almost to Silver Creek the basin lying N. of the axis H is limited by the axis F. The highest coal-beds embraced by it at the passage of Casca William Creek are the near equivalents of the Peach Mountain Seam—most probably those next above it, as our Section will show; but on Silver Creek, where the basin is narrowed, and these upper coals are lifted off by the introduction of the axis G, the highest strata preserved in it embrace coal-beds which are three or four in order underneath the Peach Mountain, or those about the horizon of the Adam Stahl Vein of Casca William and Bushy. We thus perceive that the trough immediately N. of the anticlinal H, from Silver Creek westward to the Norwegians, contains an essentially lower group of coals than the wider trough H F, stretching from Lick Run eastward; and as we advance to the Westward, we find the coals belonging to the trough to be a little lower in position on Mill Creek and East Norwegian than on Silver Creek and Zachariah's Run. They are there, in fact, the Diamond coals, which, in the two last-named valleys, characterise, as we have seen, the second basin N. of this, or that of the anticlinals E and F. And thus, as we proceed still further along the synclinal of H and G, the upper coals are successively thrown out, until at last, on the West Branch and on Wolf Creek, only the Grey-Ash and upper White-Ash beds are preserved from denudation. This change of the Coal-measures along the line of the same trough is a necessary consequence, as already intimated, of the obliquity of the undulations to the general N. border of the coal-field.

From Bushy Valley to Lick Run, the synclinal line of the basin N. of the anticlinal H is, in virtue of the steepness of the N. side of that axis, much S. of the middle of the belt; but at Silver Creek, and thence Westward, the introduction in the middle of this belt of the separate anticlinal G alters the structure of things, and by the comparative feebleness of the flexure G, places the synclinal belonging to the N. dips of H on the N. side of the now contracted trough. This is its position as long as the axis H preponderates over G, but when, as on the W. of Mill Creek, the latter becomes the sharpest and highest, the synclinal between them, as a consequence, lies closest to the opposite or S. side, and this will represent a general law for the position of the synclinal lines to the anticlinals which enclose them. The anticlinal H, the influence of which we have been tracing, forms throughout its whole length the N. boundary of the well-maintained basin of the Tracey and Peach Mountain coals; and to the consideration of this basin, and of the axis which marks its S. limit—or, in other words, the Peach Mountain range, as it is sometimes called—I propose now to proceed.

Peach Mountain Synclinal Belt.—This belt, when first clearly discerned, is marked by a simple synclinal structure of remarkable persistency. This is first visible on the high ground W. of Sillimanville, between that place and Bushy Creek, where it presents the character of an open and shallow trough, lying immediately S. of the anticlinal which was wrought by an air-shaft on both the dips by Mr Bennett. This synclinal is intersected by the Bushy Creek and Casca William Railroad, a little above their junction, where the peculiar sandstone and conglomerate, forming the base of the Peach Mountain group, are seen well exposed in gentle N. and S. dips on the opposite sides of the basin. Traced towards the W., the basin becomes closer and deeper, and on Lick Run assumes the form of a steep synclinal or **V**, in which the measures are vertical on the S. side, and dip moderately towards the S. on the opposite side of the basin. Here a seam of coal has been mined by Mr Robinson within the trough, and on both dips of the synclinal.

The basin becomes more closely folded as it extends Westwardly; and on Silver Creek, a little above the Old Valley Furnace, is seen to have this structure in a very remarkable degree. Here the two sides of the trough are closely folded together; the pebbly sandstone forming the bottom of the Peach Mountain basin is thrown on the S. side into an inverted dip in correspondence with the general inversion of the measures for some distance S. of the basin, and thus both sides of the basin dip towards the S. in nearly parallel, but slightly diverging planes, at an angle of about 40°, as exposed a little W. of the furnace. The slates and shales which separate the chief coal-seam of the group from the underlying sandstone are similarly folded, and enclose between them this coal-seam, which is seen to be doubled upon itself, and, as might be expected, is greatly compressed and in a crushed and faulty condition. On the open high ground E. of this exposure on Silver Creek, the two limbs of the synclinal may be traced by two parallel lines of shafting which extend Eastward to the workings in Lick Run. The upper bed of the hill marks the N. outcrop of the conglomerate sandstone at the bottom of the Peach Mountain group, which here dips towards the S.; and the S. margin of the basin is indicated by the perpendicular and inverted dips of the rocks which form the N. part of the anticlinal adjoining the basin on the S. These are well seen on the road leading from the Furnace to Lick Run, where it descends in a somewhat Northerly course into the valley of the latter. After passing towards the S. obliquely over the folded measures of the anticlinal in question, and across the axis-line itself, this road curves onward again towards the N., and as it descends to the valley of Lick Run discloses the rocks of the N. side of the adjoining anticlinals in nearly vertical dips. On Silver Creek the Peach Mountain coal is mined on the W. side of the valley by Capewell, Dovey, and Southall.

In these workings we find that the synclinal structure is accompanied by a dislocation or fault; the Northern or South-dipping limb of the synclinal is prolonged downwards below its intersection with the Southern limb, here called the Perpendicular Vein, giving to the two together a form somewhat like that of the letter Y. This may be conceived to have arisen from a fracture at the bottom of the V, accompanied by an upthrow of the S. side of the trough.

The zone of the N. dips is much narrower than that of the S. dips, a feature due, Eastward, to the nearly vertical stratification of the Sharp Mountain, and the abruptness of the anticlinal, together with its general depression as compared with the crest of Locust Mountain. Prolonged in the same general direction, and with the same structural features, the Peach Mountain basin may be traced across the watershed to Zachariah's Run, where a South-dipping and a perpendicular vein have been opened in it, forming the synclinal basin.

From Zachariah's Run the synclinal may be traced across the hills to Ravensdale and Crow Hollow, and thence to the E. side of Mill Creek, by an irregular but observable depression of the surface lying a little N. of the line of the anticlinal already mentioned. In the interval between Zachariah's Run and Ravensdale, the basin loses its folded structure, becomes wider, and towards the S. edge includes an anticlinal roll or subordinate axis within its limits. These are its features, as observed a little N. of Singley's, and in its course thence to the Ravensdale Hollow. Here sandstone and conglomerate, underlying the Peach Mountain coal, may be well seen a few hundred feet S.E. of Mr Dovey's dwelling, dipping always to the S., and again on the side of the railroad, a short distance towards the S., with the opposite or N. dip. Between Zachariah's Run and this, the Peach Mountain coal has been shafted on in many places, and at certain points has been partially mined.

The measures next below those of the Peach Mountain group—viz. the Tracey conglomerate and slate—show themselves on the E. side of Mill Creek in a synclinal form at the junction of the main road with a lateral road to Crow Hollow. On the W. side of the valley the basin extends along the depression through which the road from East Norwegian runs Eastward towards Mill Creek. Here may be seen the cropping of the Peach Mountain coal, both on its N. and S. dips, in a very narrow and shallow basin, the N. margin of which lies a little S. of the position of the Summit Tavern. The anticlinal detected within the basin between Zachariah's Run and Ravensdale is continued across Mill Creek, and in the locality now in view forms the ridge immediately S. of the depression in which the Peach Mountain coal occurs. The S. dips of this anticlinal are very gentle, giving to it the character of a mere undulation on the N. flank of the great anticlinal which adjoins it on the S., and which is but the prolongation of that already spoken of as marking the S. boundary of the Peach Mountain basin, in its extension from Casca William towards the W.

In its prolongation Westward of this point, the Peach Mountain belt presents a more complex structure, having the character of a chain of troughs or synclinals in an oblique parallel arrangement, but in one general direction, and either partly or wholly separated from one another by interposed anticlinals.

PEACH MOUNTAIN ANTICLINALS.

Anticlinal I., *or Main Axis of Peach Mountain.*—S. of the folded trough of the Peach Mountain coal, at a distance varying from 400 to 600 feet, ranges the leading anticlinal axis, the first traces of which towards the E. we detect in the hill S.W. of Milford Tunnel. We recognise it next on both sides of Casca William Valley, a few hundred feet S. of the junction of this and the Bushy Valley. It is here a normal anticlinal, its S. dips near the axis being gentle, and the N. dips only moderately steep. We encounter the axis again on Silver Creek on the hill immediately S. of the old Valley Furnace, and in the valley next E. of this; but in this vicinity, and Westward the whole distance as far as Ravensdale, it has the structure of a folded anticlinal, or one inverting its Northern dips into Southern ones. From Ravensdale to East and West Norwegian, this axis is much more dilated, presenting on its N. flank but moderately steep, and sometimes even gentle, N. dips. Where the anticlinal is a flexure with inversion, and the Peach Mountain synclinal N. of it is necessarily of the same character, it is brought much nearer to this latter than where they are both of the normal or open form. We see them thus compressed and approximated on Silver Creek and Zachariah's Run. This axis, like others of its group before described, observes a very gently-inflected line of direction, concave Southward, especially in the region of Silver Creek and Zachariah's Run, where it is most closely folded.

The coal-beds lifted to the water-level of the country in the range of this anticlinal are for the most part the two or three immediately subjacent to the Peach Mountain bed—that is to say, the Big and Little Tracey coals, and the Little Peach Mountain seam next under the main one: the lowest of these three, the Big Tracey, is exposed in the axis on Casca William Creek. The next over it, the Little Tracey, has been there opened, but is locally designated the Clarkson Vein. The Chas. Potts Vein of that place is probably the Little Peach Mountain, and the Palmer the Peach Mountain Proper. On Silver Creek, the third coal beneath the Peach Mountain Vein, the Big Tracey of Mill Creek and East Norwegian, is lifted, and denuded into two outcrops at this anticlinal; and here the next above it, or the Little Tracey, is called the Chas. Pott Vein on the S. side of the axis; and equally erroneously, that which next overlies the equivalent of the Little Peach Mountain is here styled the Palmer Vein. The Peach Mountain, on this S. dip of its Silver Creek anticlinal, is in all probability the second, possibly the first, under the so-called Spohn Vein of the locality; unless, indeed, there is an interpolation of a thin bed, in which case the Spohn Vein and the Peach Mountain are the same coal-seam. This axis, rising gradually as it reaches Ravensdale and Mill Creek, brings to the surface apparently two or three coals lower than the Big Tracey seam, but, expanding and flattening in ranging further Westward, lifts in the East Norwegian Valley only the Big Tracey above the water-level.

Anticlinal I, *or Southern subordinate Saddle of Peach Mountain Axis.*—In speaking of the structure of the Peach Mountain belt of the Pottsville Basin, it has been stated that in some districts the main anticlinal is accompanied by one or more parallel subordinate saddles, or, what is nearly the same thing, that the whole anticlinal zone comprehends usually one long though not continuous axis, flanked by one or two shorter and still less continuous saddles. In the district before us we meet with one of these attendant smaller undulations, a little S. of the chief one, at a distance of usually from 400 to 600 feet. The first Eastern exhibition which we have detected of this saddle is in the watershed between Ravensdale and the brook next E. of it. It is seen near the road leading E. from Ravensdale, and a little S. of the junction of the Ravensdale and Crow Hollow streams; and we meet with it again in the hill dividing Mill Creek Valley from East Norwegian, where it forms, indeed, the main summit to the S. of the Peach Mountain basin. In its range W. from the latter valley, it is this axis which seems to constitute the true crest of the so-called Peach Mountain; the other anticlinal of the belt, or axis I, so much more important than it, to the E. of Mill Creek, becoming, in its more Western range, but the subordinate companion of this one, forming, indeed, but a roll, as it were, upon its N. flank.

On Mill Creek and the East Norwegian, the axis I lifts out the Big Tracey coal into a North and a South-dipping outcrop, and it is by virtue of the greater prominence of this anticlinal here, as compared with axis I, that the Big Tracey coal is spread out on the East Norwegian in an undulation so much flatter than is presented by any of the other coal-beds not thus involved in the double anticlinal.

CHAPTER V.

SOUTHERN COAL-FIELD BETWEEN TAMAQUA AND SILVER CREEK, ITS ANTICLINALS, BASINS, AND COLLIERIES.

Anticlinal Axis C.—Resuming our detailed description of the flexures of the coal-field at the Little Schuylkill, the first or most Southern anticlinal axis which we trace thence is that of the ridge bounding Tamaqua on the S. This axis is seen in the bank of the Wabash, at a short distance above the spot where the stream is crossed by the railroad, and from this point the anticlinal line appears to observe an almost straight course along the crest or brow of the ridge or plateau S. of the Wabash Valley for nearly a mile; thence it pursues the valley of the Wabash past Newkirk and Bucksville, W. of which latter place it occupies the S. brow of the ridge bounding the same valley on the N., till it passes S. of the Tuscarora Colliery (Tucker's Slope) at the intersection of the road and railroad; thence its course is to the mouth of the Palmer Tunnel.

Of the dips connected with this axis very little can be said in detail, or is indeed called for, because few or no openings of any sort have been made in it, except near the Little Schuylkill, and E. of Tuscarora. In the vicinity of Tamaqua it does not appear to be a much compressed or steep saddle. The gently-rounded outline of the edge of the plateau which it follows, and the dips visible near the axis, as indicated in our Section, go to establish the fact of the Eastward flattening of this flexure. In accordance with this feature of its Eastward declension, we observe an absence of all external or topographical indications of it E. of the Little Schuylkill. If it reaches Sharp Mountain at all, it is only as a roll in its flank. Passing W. of Tamaqua, this axis increases in force, both its N. and S. dips growing much steeper than at Tamaqua, where they are as low as 30°. The very steep dips in the compressed synclinal fold which we see at the foot of Sharp Mountain at Tamaqua, are due less to the sharpness of the anticlinal than to the forward pressure and overtilting of the Sharp Mountain at the other or S. side of the basin.

Basin D.—Of the *coal-beds* embraced in the basin or trough between this anticlinal and Sharp Mountain, there is nothing of value to add to what has been already mentioned respecting those visible at the Little Schuylkill, and displayed in the Tamaqua Section. The highest must evidently belong to the lower Red-Ash coals ; but it is manifest, from what we behold at the foot of the mountain, that those at least which are most involved in the squeeze at the synclinal axis are not likely to be in a very sound or suitable condition for mining. The beds arching the anticlinal are, from the absence of compression, and from their gentler dips, in a probably more unbroken state, but they have been insufficiently explored. At Tuscarora there are three saddles S. of this one, or between it and Sharp Mountain ; but the description of them is deferred to a later section.

SECOND AND THIRD TAMAQUA ANTICLINALS AND RELATED BASINS.

Axis B.—The next axis of Tamaqua, that N. of the town, is visible on the E. side of the Little Schuylkill some 400 feet N. of the Mauch Chunk Road, and on the W. side in the hill or bluff immediately bounding the Wabash Railroad on the N. This it crosses further Westward to range along the crest or summit of the ridge running from Tamaqua to Newkirk. The abrupt arch of this anticlinal is seen at Newkirk, just E. of the Upper Coal-Breaker ; but how far Westward it extends from this point is at present not ascertained, though it probably reaches Buckville. This is a sharp or closely-folded saddle, the dips on both sides of the axis being very steep, the Southward 70°, and the Northward even nearly 80°. The annexed cut (fig. 147) shows the overturned outcrops of the strata *both ways* from this axis.

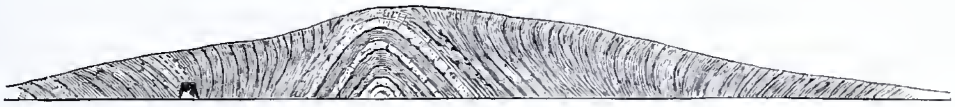


FIG. 147.—Anticlinal Axis B, near Newkirk, with overturned outcrop.

Mention has already been made of all that can be determined respecting the coals exposed in this anticlinal, or contained in the basin *C b* of the centre of Tamaqua south of it. Counting the coals visible at Newkirk, between the ascertained beds of the tunnel there and the valley of the Wabash in the synclinal on the S. of this axis, I am disposed to estimate the highest in the latter position as about the ninth or tenth above the first Red-Ash bed, or Grier Coal, so called, of the Slope Mine No. 1, near the mouth of the tunnel. Only the lower portion of these coals at Newkirk lies within the trough *b*, N. of this axis B ; that is to say, between the second and third Tamaqua anticlinals. The condition of things is therefore about the same as at the Little Schuylkill. The synclinal line of *b* is a very short distance N. of B, and the flexure is *folded*, or the N. dips of *b* are steep, or even overturned below.

Axis B.—*The third* and Northernmost anticlinal of the Tamaqua district, that which I am disposed to consider as the Summit Hill axis, lies N. of the one just described only about 650 feet on the E. side of the Little Schuylkill. How far it is prolonged Westward it is impossible at present to determine, but a flexure met with at Newkirk, both in the surface strata and in the slope S. of the tunnel, is very probably this same axis somewhat enfeebled towards its termination. Their identity, however, is uncertain; but that there are two undulations at Newkirk is pretty evident; and this, the more Northern one, is very probably the undulation within the mine. If so, its position will take it, if it is prolonged, into Locust Mountain north of the Buckville Tunnel. The other, or Middle Tamaqua axis B, already traced N. of the main Mine Hill anticlinal C, is not extended apparently as far as the Buckville Tunnel, notwithstanding its steep dips between Tamaqua and Newkirk.

Of the coals in the trough *B b* between these two saddles nothing is to be added to what has been said of the vicinities of Tamaqua and Newkirk, for the presence of neither axis is yet established at Buckville.

Of the coals which are embraced between the N. axis and the flank of Locust Mountain, a general view is to be derived from the N. part of the Tamaqua Section. The notes and sections exhibiting the condition of things at the Newkirk and Buckville Tunnel will, with the Tamaqua details, give the reader all that was known in 1853 of the individual coal-beds, and the extent to which they were mined in the belt occupied by the two anticlinals.

BASIN *B*, REINHARDT'S RUN, NEWKIRK TUNNEL.

Newkirk Tunnel.—Coal E has been worked through to meet the great coal E of Tamaqua. The gangway from the tunnel has been carried E. at a level 90 feet higher than that from Tamaqua, and has passed it by about 45 feet. A hole has been driven up from the latter into the former.

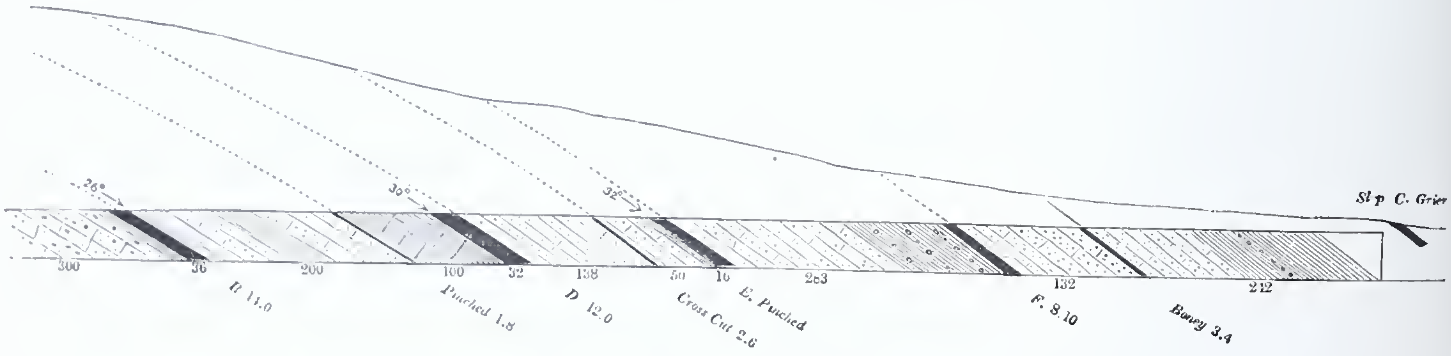
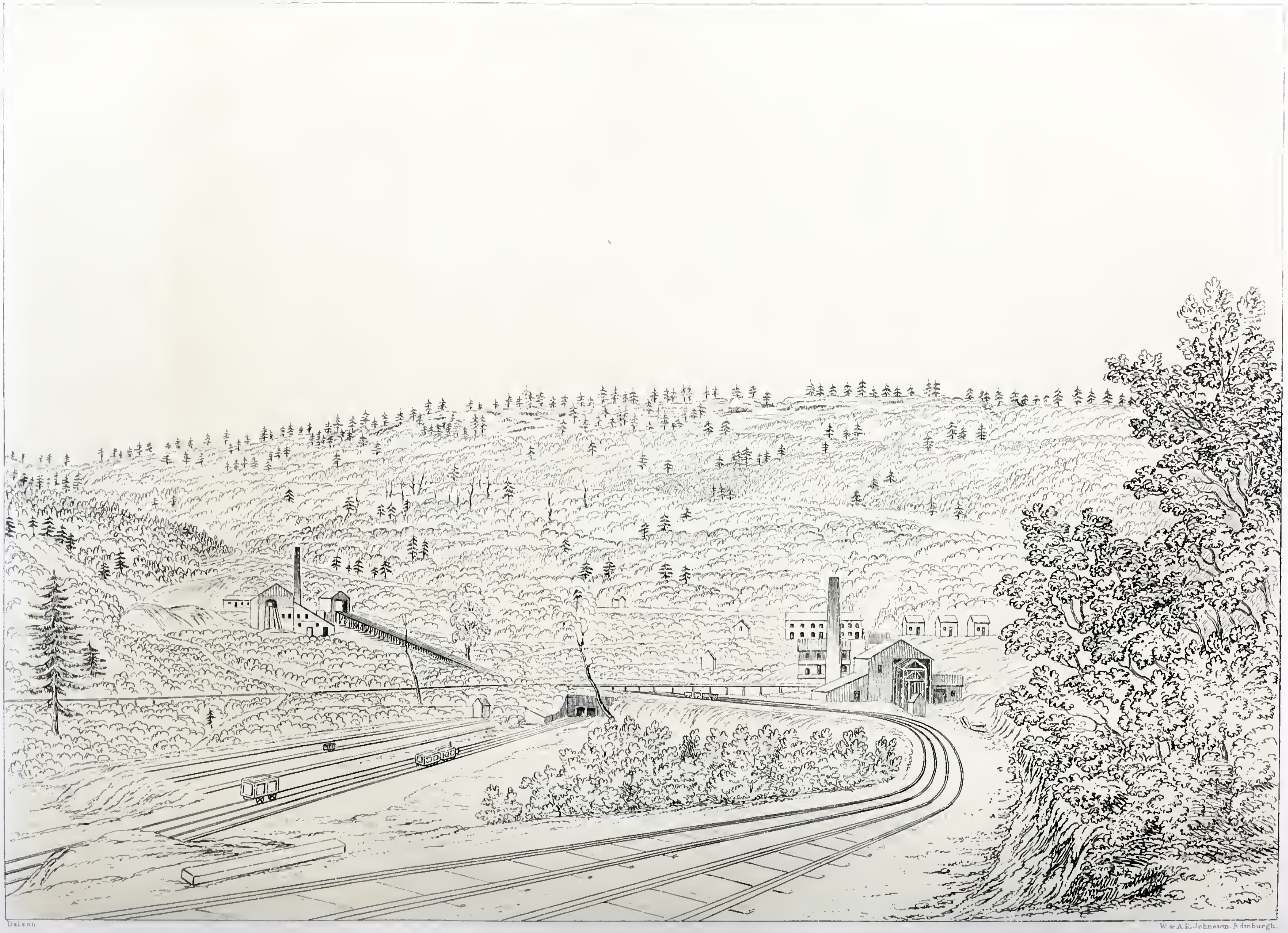


FIG. 148.—Section of Newkirk Tunnel.

The bed first N. of D has been driven 400 yards E., and 400 yards W. of the tunnel. (This is the Pinched coal of our Section.)

Details of the coal-seam north of D (Coal C)—

Slate, ...	2½ to 4 feet.
Coal, ...	10 inches.
Slate, ...	15 inches.
Good coal—(This vein yields a strong Red Ash), . .	3 feet.



Dalson

W. & A.K. Johnston, Edinburgh.

NEWARK TUNNEL COLLIERY NEAR TAMAQUA

Film or parting,	1 inch.
Better coal,	5 feet.
Slate,	2 inches.
Coal,	4 feet.
Slaty coal,	2 feet.
Good coal—best,	3 feet.

Two hundred yards W. of the furnace the air-shaft on the vein is 287 yards above the gangway by the slope; the dip is 30°. On the same vein the air-shaft from the summit is 726 feet to the surface; the dip 28°. 200 yards E. of the tunnel the air-shaft on this bed is 283 yards to a gangway; dip 42°. The vein is faulty to the E., but good to the W. The faults are due E. and W. This is the most N. vein cut in the tunnel; it is still disputed whether it is B or C of Tamaqua.

R. Ratcliff and Co. have a slope (No. 3 Mine) on F vein below water-level. Bowman and Richardson have a slope on the large vein called Bowman's Vein (Slope No. 1) below water-level. A rock-fault occurs in F, driven W. under water-level by Ratcliff.

The cross-cut vein on the W. side of the tunnel is 60 feet from Coal D. It is composed of—

Rough coal—bird-eye,	1 foot.
Good coal,	2 feet.
Slate,	—

On account of the goodness of this coal, they are now taking from this thin vein about two-thirds of all they work. In the year 1853, about 500 or 600 tons per week were mined.

It is conjectured by some persons that Wiggan's coal is the Tamaqua bed C.

Vein F of Newkirk Tunnel has been connected with that of Tamaqua by a hole from the former down to the latter about 60 feet deep in the vein.

The coal E at the Newkirk Tunnel is reduced to only 1 foot or 15 inches. Going E. it increases rapidly. It has been worked E. about 800 yards. At half that distance it is about 12 or 15 feet thick; and at a distance of about 600 yards, at the E. end of the gangway, it is about 30 feet thick; it then thins again as we go forward, and at 800 yards is about 12 or 15 feet.

This vein varies so much in its subdivisions that no account can be given of its composition.

The F vein is at the tunnel 7 feet thick, and 100 yards E. from the tunnel it is 17 feet. 300 yards further it is about 22 feet, and this continues to the end of the East gangway about one mile above water-level. It had been worked at a distance of 150 feet below the upper gangway, or for 600 yards to the E.

It had also been worked to the W. 600 yards in a gangway above water-level, where a rock-fault comes in. The gangway below the water-level struck the same fault at 100 yards.

Dimensions of F vein on the E. side, where it is about 17 feet thick,—

Top slate,	—
White clod or clay—fire-clay,	2 feet.
Good glassy White-Ash coal—no slate,	7 „
Bony coal,	2 inches.
Very good coal—Pink Ash,	8 feet.
Shaly coal and dirt,	2 „

On the W. side, before coming to the fault on the upper lift, it begins at the tunnel at 11 feet thick, and is increased to 20 feet at about 600 yards. Then it is nipped close; but on the rise in the breast, about 30 yards above the gangway, it was 40 feet thick, the coal being rather faulty. The dip of coal F in the slope is about 33°, being steeper below and flatter above.

In Bowman and Richardson's Slope three veins are opened.

From the F vein S. to Bowman's Vein is 100 yards by a tunnel. This intersects 30 yards of slate on the top of F, and the rest is blue sandstone until we reach slate under Bowman's Coal.

From Bowman's Big Vein to the Little Vein the distance is 20 yards of slate. The dip of the Big Vein is 40°; that of the Little Vein is 45°.

A tunnel from the Little Vein to that next S. of it, called Big Diamond Vein, is about 100 yards long, the first half being slate and the rest sandstone.

There is sandstone above the Big Diamond Vein. The Bowman Big Vein is supposed by some to be the Grier. The distance of the Grier Vein from F at Tuscarora is 101 yards.

Bowman's Vein runs E. It is 100 yards to the rock-fault, which is not passed. The coal varies in this distance from 11 feet to upwards of 40.

When regularly worked it is about 9 feet thick. The coal at Bowman's is Pink Ash.

Fireclay, top clod white,	1 foot.
Good coal, but a little faulty,	4 feet.
Coal slate,	3 inches.
Good coal,	5 feet.

Bowman's Little Coal or Grey Ash is from 4 to 6 feet thick. It is generally a 4-feet vein, the bottom bench being 2½ feet; above this, 2 inches of slate, and then about 1½ feet of rough coal.

The Big Diamond Vein at Bowman's is about 9 feet thick, but in fault. It is not worked. This is pure Red-Ash coal.

About 20 yards S. of the outcrop of the Big Diamond Vein is another South-dipping coal, which has been proved, but not worked. It is called the Little Diamond Vein, and contains about 3 feet of good coal.

Another vein, about 3 feet thick, has been opened by a drift under the first screen. It is about 100 yards S. of the Little Diamond Coal.

South of the same seam, about 100 feet, is a small seam 2½ or 3 feet thick, dipping S.

There is a coal-drift 200 feet still further S., on a hill. It displays a bed about 7 feet thick.

A vein with a S. dip has been struck in a well at the Schoolhouse. It is small, and about 50 yards S. of the preceding. A short distance still further S. another coal has been struck, and still another bed, said to be thick, has been reached in a well on the S. side of the village near the main railroad.

COALS.—At Newkirk the *Grier Coal* is mined by a slope; it lies about 315 feet S. of the coal F, and is called Bowman's Big Vein. Its regular thickness is 9 feet. 100 yards W. of the tunnel it runs into a rock-fault. In this distance it varies from 9 to 40 feet in thickness; the dip at the slope is 40° S. It has a pink ash.

Coal A of Tamaqua.—The Newkirk Tunnel will ultimately reach this coal. Its outcrop is on the S. brow of the Locust Mountain.

Coal B.—This seam had not been reached at the date (1853) of our last examination of the district. Its outcrop is high on the slope of Locust Mountain. It has probably been cut in Newkirk Tunnel by this date.

Coal C.—The first vein North of D in the Newkirk Tunnel (C ? of Tamaqua), was, at the date of our last observations, driven 400 yards E. and 400 yards W. of the tunnel. It is a strong Red-Ash coal. About 600 feet W. of the tunnel an air-shaft led 287 yards up the breast. The air-shaft from the tunnel is 242 yards up the breast, and 200 yards E. of the tunnel an air-shaft is 180 yards up the breast. The *dips* are severally 30°, 28°, and 42°. The coal-bed is faulty to the E., but good to the W. Its average *thickness* is about 17 feet. There is no doubt but that the first vein North of D in Newkirk Tunnel is C of Tamaqua. Ratcliff's line of air-holes on D, West of Tamaqua, are extended nearly opposite the end of Wiggan's Working, in this disputed vein East of Reinhardt's Run. The interval between the two ranges of outcrop is just that between C and D at Tamaqua. Vein C at Tamaqua is underlaid by about 4 feet of slate, below which there is a thin coal-seam not wrought. In the mine at Newkirk Tunnel the slate-bed is reduced in thickness, and becomes a slaty coal; and the underlying coal, here 3 feet, is wrought with the rest. This bench is a strong *pink-ash* coal. It is interesting to ascertain whether the bench below the slate at Tamaqua would yield a coal of the same kind.

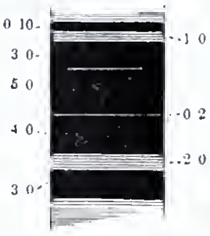


Fig. 149.—Coal (B ?) C, Newkirk Tunnel.

Coal D.—Has been driven through from Tamaqua. Its dip is flatter than at Tamaqua, being 42°. The quality of the coal is the same.

Coal E.—This bed, in 1853, was worked through from Tamaqua to Newkirk Tunnel. In the tunnel it is only 12 or 13 inches thick; it has been mined E. from the tunnel about 800 yards. At 400 yards it is about 12 or 15 feet thick, at 600 yards, 30 feet, and then declines to 12 or 15 feet. The outcrop of this admirable seam of coal is traceable, by its air-shafts, along the flank of the Locust Mountain at a high level, the whole distance from the Little Schuylkill to the Newkirk Tunnel, and thence, indeed, to the tunnel at Buckville. Its position on the surface at Buckville is vertically over the intersection of Coal D by the tunnel.

Cross-cut Coal.—About 60 feet W. of the Newkirk Tunnel this coal consists of 2 feet of hard glassy coal, capped by one foot of bird-eye coal. It is largely wrought on account of its purity. It lies 45 feet S. of coal E.

Coal F.—The dimensions of this bed at Newkirk Tunnel are 7 feet. About 100 yards E. of the tunnel it measures 17 feet thick; 200 yards further E. it is 22 feet thick, and continues thus to the end of the gangway, or one mile from the tunnel. Its thickness on the W. side of the tunnel is 11 feet, and 600 yards further W. it is 20 feet; it is then nipped, and at the water-level it is 40 feet thick, and faulty. Its dip is 42° S.

It has been worked E. from Newkirk Tunnel one mile above water-level. In a gangway from the slope, 150 yards lower in level, it was worked E. 600 yards. From the tunnel-level it was mined 600 yards W. There a rock-fault appeared: lower down, or in the slope-level, the same fault was met. This has since been driven through. The Newkirk mines in this coal have been connected with those of Coal F of Tamaqua by a hole 60 feet deep, sunk from the end of the Newkirk level.

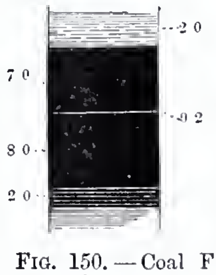


Fig. 150.—Coal F, (thickened), Newkirk Tunnel.

Bony Coal.—This coal has been cut in Newkirk Tunnel, where it is 3 or 4 feet thick.

Collieries.—The Reinhardt's Run property, owned by the Little Schuylkill Company, is leased by four different parties, each of whom owns separate breakers. Beginning with the most Northern, these collieries are—1. Ratcliff; 2. Bowman; 3. Jones and Cole; and, 4. Wiggan and Son.

Newkirk Tunnel.—In 1853 this was driven somewhat more than 400 yards, cutting all the veins N. of the Grier Coal as far as B (see Section of the Tunnel). Most of the coals cut have gangways upon them, worked one mile E. as described. It is leased by Wiggan and Son.

Bowman's Slope.—This old slope, situated a short distance S.E. of the mouth of the tunnel, is sunk on the Grier Vein of Tuscarora, here called Bowman's Big Vein. This slope is 315 feet S. of coal F in the tunnel.

The *New Slope,* on coal F, is situated N.W. of the tunnel mouth about 450 feet; it is down 150 yards. The dip at the top is 42°, and at the bottom 38°. The gangways have been driven E. and W. from the foot of the slope.

Coals in Basins B b and C b.—We may infer from the oblique direction of the basin *B b* from the Little Schuylkill to Reinhardt's Run, that towards the latter stream it must contain rather lower coal-beds than at the former; in other words, that one or two of the upper Red-Ash coals of Tamaqua may head out within this basin in going W. This tendency will, however, be somewhat counteracted near Reinhardt's Run by the dying-out of the anticlinal B.

The *Basin C b*, or that of Wabash Creek and Newkirk, will, on the other hand, be found, I think, to retain all the coals at Newkirk which it possesses at Tamaqua, for it rather expands in going W., until it opens into the main N. basin of Buckville, of which it is a branch.

COALS CONTAINED IN BASIN *C*, ON THAT OF THE BUCKVILLE AND PALMER TUNNELS.

Buckville.—The anticlinal axis B of Tamaqua, expiring Westward in the neighbourhood of Reinhardt's Run, and that next S. of it, b, not appearing to reach Buckville Tunnel, we are entitled to assume that from the latter locality, Westward to Big Creek, there prevails but one basin C, between the main axis of the valley and the top of Locust Mountain. The synclinal axis of this basin probably passes a little N. of the Buckville Breaker. Of course only the S. side of the whole basin, or that between the tunnel and the anticlinal C, contains the Red-Ash coals; all the N. half, or that occupying the slope of Locust Mountain to Coal E in the tunnel, being allotted to the White-Ash beds. The axis opposite Buckville must lift to the surface lower Red-Ash beds than it does at Tamaqua.

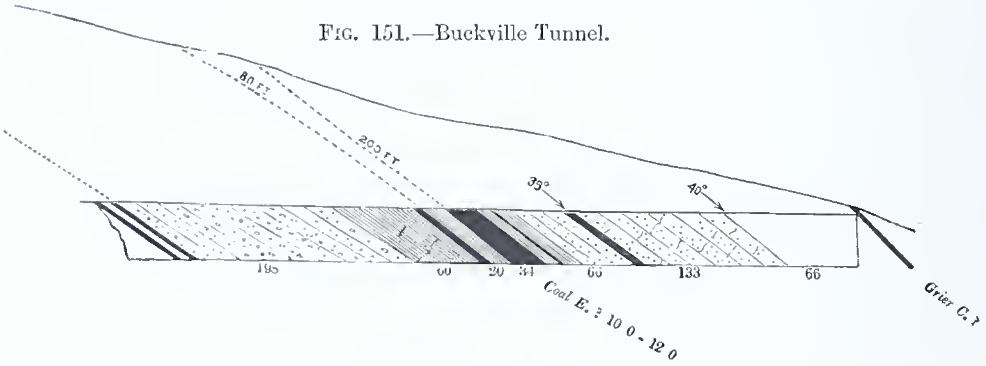


Fig. 151.—Buckville Tunnel.

Coals.—*Coal F* (here also called the Grier Vein) is worked by a slope; its thickness is from 10 to 12 feet; the dip S. 40° to 45°.

Coal E.—This is worked E. from tunnel 600 yards, and the same distance W. Thickness of coal about 18 feet: for its subdivisions, see the accompanying cut (fig. 152). In the level 300 yards E. of the tunnel they have driven N. across to the Cross-cut coal.

Coal D.—In the tunnel the next coal North of coal E is worked W. about 170 yards. Separated from the Cross-cut coal by 10 feet of slate, they are wrought together. The most Northern vein in the tunnel is double: the two coals are each 6 feet thick, with 20 feet of rock intervening in the tunnel, but 35 or 40 feet W. they come together, and the coal becomes dirt, and is valueless.

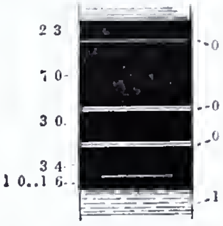


FIG. 152.—Coal E, Buckville.

Between the mouth of the tunnel and the breaker are the outcrops of four coals, all of them belonging to the lower Red-Ash group. These are the highest beds of this part of basin *C.*

Colliery leased by Jones and Cole.—There are two mining operations here, a *tunnel* and a *slope.*

The *slope* is in coal F, just W. of the mouth of the tunnel, and is down 318 feet; the dip is S. 40° to 45°. The thickness of the coal is 12 feet at the top of the slope, and from 10 to 11 at the bottom; between, the coal is very thick, but not so good.

PALMER TUNNEL.—This tunnel, leased by Charles Silliman, has its mouth just N. of the anticlinal C, from whence it penetrates the basin Northward to the Big Vein, or Coal E of Tamaqua. It commences a little N. of the outcrop of the South Mortimer Coal, so called, and passes the synclinal axis of the basin between the next bed, the North Mortimer and the Grier Coal, these two being but the same bed with opposite dips. Cutting now only South-dipping measures, it crosses the Bony, the Palmer, and three other thinner beds, before it reaches the Big Coal, 97 yards N. of the Palmer. In this latter space it cuts 20 yards of slate, then a coal 2 feet thick, then sandstone 20 yards, a coal 4 feet thick, and at 22 yards further another coal 5½ feet thick; the remainder of the space is a hard pebbly rock.

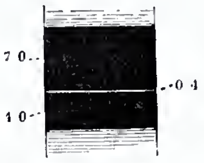


FIG. 153.—Tuscarora, or Palmer Coal of Tuscarora.

The Palmer Coal is from 12 to 14 feet thick, and is mined both E. and W. of the tunnel; in the latter direction a rock-fault, now passed, throws the bed about 60 feet N. of its true line of strike.

The Big Coal averages 20 feet in thickness; in the tunnel it dips 65° S., and E. of it, 45° S. West of the tunnel the dip is more constant. The breast of this coal is about 100 yards.

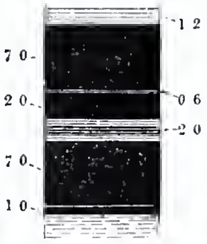


FIG. 154.—Coal E, Palmer Tunnel.

TUCKER'S SLOPE, BASIN C.

COALS.—*The Grier Coal.*—This is the coal of *Tucker's Slope,* half a mile E. of Tuscarora. Mr Kendrick, the mine captain, informed us that the bottom bench is Red Ash, 20 inches or 2 feet thick, while the top bench is Grey Ash, 3½ feet thick. It is good hard coal, somewhat streaky, though not so much so as the top bench, which is also a hard coal.

The coal called the Palmer Coal, cut by a tunnel driven N. from the Slope coal at Tucker's, and also cut in Palmer's Tunnel W. of Tuscarora, is no doubt the F coal of Tamaqua. In the Palmer Tunnel this coal is from 12 to 14 feet thick; it has lately been reached E. of Tuscarora.

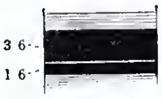


FIG. 155.—Grier Coal, Tucker's Slope.

The *Tuscarora Coal* is supposed to be the same as the Palmer Coal. This coal lies in two benches, the lowest being 4 feet thick, Red Ash, and a clear flinty hard coal; and the upper 7 feet thick, of streaky Grey-Ash coal.

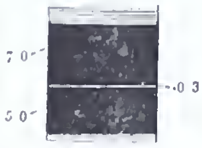


Fig. 156.—Palmer Coal, Tucker's Slope.

Tucker's Slope is on the Grier Coal, and a little more than half a mile E. of Tuscarora. It is 150 yards to the bottom of the slope, which is 90 yards below water-level. A gangway has been driven 135 yards to the E., and 1200 to W. It encountered a remarkable dislocation at the end of the E. gangway (October 1853). From the bottom of the slope a tunnel was driven N., and cut the Palmer Coal (Coal F of Tamaqua). This has been wrought about 1400 yards W. of the tunnel, where it struck a rock-fault (1853). It was driven E. about 1400 yards, or within 25 yards of the line of the Little Schuylkill company. A slope has lately (1853) been put down by Reuben Jones 95 yards E. of the Tuscarora (Tucker's) E. line; this is on the Palmer Coal, or F coal of Buckville, and therefore of Tamaqua.

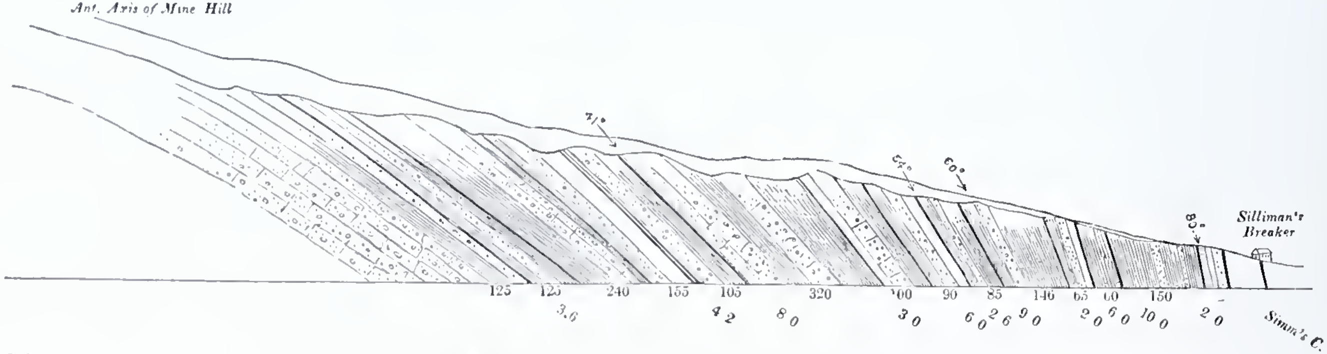
Basin C D, or that of Tuscarora.—This wide and regular sub-basin, the W. extension of basin *D* of Tamaqua, runs obliquely from Sharp Mountain to the S. foot of Mine Hill, and is thence prolonged between Mine Hill and the craggy ridge we have called South Mine Hill; its greatest depth is probably S. of Buckville, unless one or more subordinate flexures, *c* and *c c*, of Tuscarora, extend thus far E., and undulate its bed: it evidently contains the lower and middle groups of the Red-Ash series of coals; the two subordinate anticlinals which disturb it at Tuscarora, and the lesser basins which they make, have been already defined.

There are four or five mining operations in progress within this basin: Carter's Slope Mines, Pott's Slope Works on Big Creek; Silliman's Slope on Big Creek; Whitfield Tunnel Mines on Du Long Creek; and the Luther or Sinnickson Tunnel on Casca William Creek.

The Big Coal of the district coal E of Tamaqua enters the basin probably W. of Swift Creek, for in the Palmer Tunnel it outcrops many hundred yards N. of the Mine Hill anticlinal C, while at Potts' Slope, on the East Branch of Big Creek north of Brockville, its place is several hundred feet S. of that axis. On Main Big Creek its outcrop at the S.E. foot of Mine Hill, at Silliman's Slope, is about midway between the anticlinals C and D; thence it runs S.W., with one or two hitches in its course, to the upper Whitfield Tunnel, where its place is but a few hundred feet N. of axis D. The Bushy Tunnel does, or did not, reach it, but it is cut by the Luther Tunnel N. of Sinnickson's Slope; and it is traceable for a great distance, indeed, along the S. slope of Mine Hill, from its E. end to the valley of Silver Creek, where the basin becomes almost extinguished.

For the positions, distances asunder, and thicknesses of the other coals within this basin, the reader is referred to the engraved Sections representing some of the localities mentioned.

Fig. 157.—Section of Strata at E. end of Mine Hill, N. of Patterson, looking E.—1 *inch* = 400 *feet*.



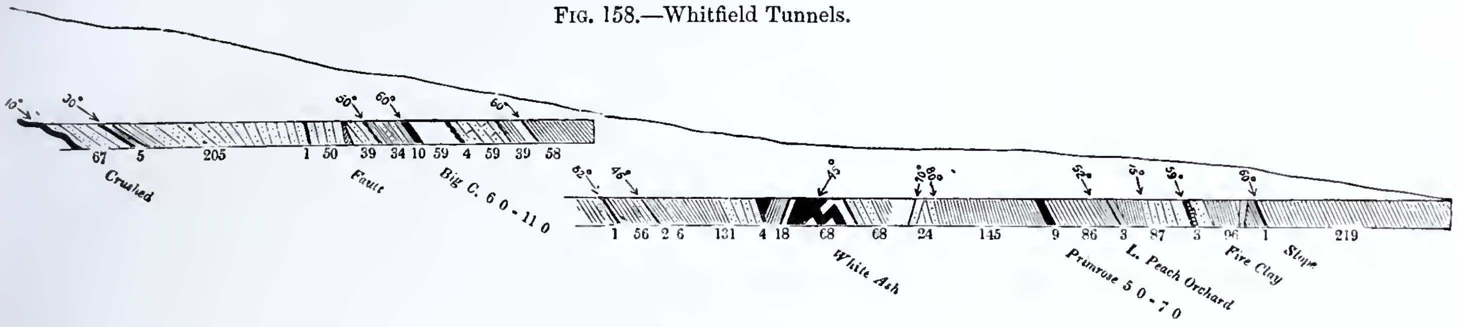
Slopes.—There are two slopes N.W. of the village of Patterson in basin *C D*, the one worked by Silliman and Meyer, the other by G. Potts; they are both working the same coal (the Big

Coal). George Potts' mine was (1853) some 20 or 30 yards below Meyer's working; the coal was not so sound as at Meyer's. He had driven both E. and W., and found his coal faulty.

Silliman and Meyer's Slope is 300 yards W. of Potts'. They have driven about 400 yards W., but not as yet to the E.

Whitfield Tunnels, De Long Tract.—The Big Coal was cut in Whitfield's Upper Tunnel; its average thickness there was 8 feet, sometimes it was 11 feet, and often 6 feet thick. There were three benches of slate between the top and middle bench; the top was sometimes rough, but the bottom always pure. In these features the two veins resembled that at Big Creek. The length of gangway E. was 400 yards, and W. 1000 yards; it was found faulty and large, being from 12 to 20 feet thick.

FIG. 158.—Whitfield Tunnels.

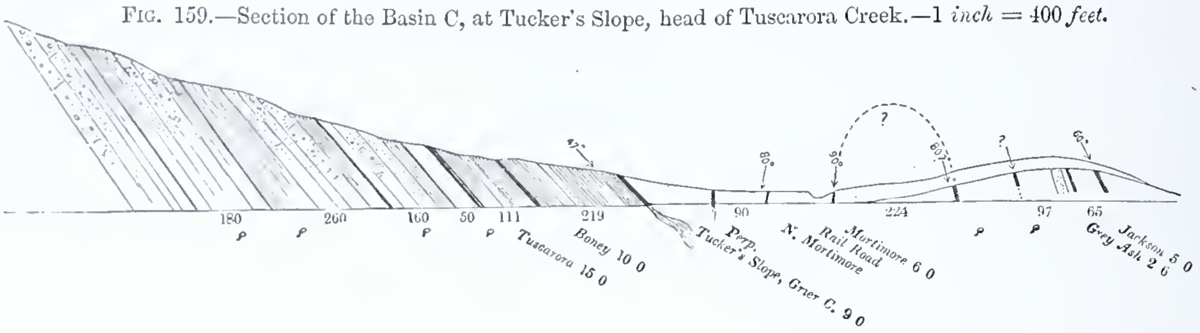


OF THE FLEXURES ANTICLINAL AND SYNCLINAL IN THE VICINITY OF TUSCARORA, AND THE COALS THERE DEVELOPED.

Axis C, near Tuscarora.—It has been already intimated that the southern Tamaqua and East Mine Hill axis, passing S. of Tucker's Slope, and of the mouth of Palmer Tunnel, ranges N. of the village of Tuscarora. Its N. dips are visible at the head of the cross street or road ascending towards the mountain, just at its bend Westward; N. of which a depression in the surface marks the basin at the foot of the mountain. The position of the anticlinal is on the next bench or terrace S. The anticlinal is cut by Swift Creek, in the gorge where this stream passes through the spur prolonged from Mine Hill. The N. dip at Tuscarora is not steep, perhaps from 35° to 40°, but such seems not to be the character of this side of the axis, except at this place and at Tamaqua; for near the intersection of the railroad and carriage-road below Tucker's Slope, the axis S. of the folded synclinal of the Slope Mine on the Grier Vein is compressed with excessively steep dips, those of the N. side being vertical, and those of the S. side 80° S.; and again at the mouth of the Palmer Tunnel, the dip of the N. flank of the saddle is perpendicular, or even a little inverted, the S. dip being here from 50° to 60°. At Swift Creek likewise the axis is thus equally compressed, even its South-dipping beds being as steep as 60°. This is not its configuration, however, where it passes Big Creek, and lifts the broad and swelling crest of Mine Hill. The more massive lower White-Ash Coal-measures, and the main egg-sized conglomerate beneath them, there rise in an ample and slowly-curving arch—only the remote abutments of which, far out from the axis, display a high inclination in the rocks.

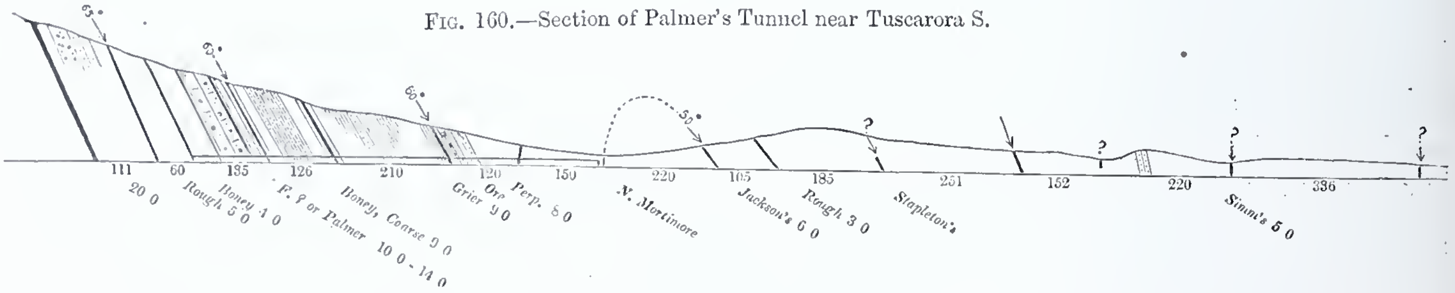
Tracing the coals which are elevated in succession to the surface by this anticlinal from the Little Schuylkill to Mine Hill, we have an interesting and instructive illustration of the progressive emergence of the whole series from those of a relatively high horizon to those resting on the conglomerate. Thus, at the Little Schuylkill, this axis brings up, as we have seen, the lower Red-Ash coals; while opposite Tucker's Slope it exposes, as our Section there shows, the lowest of the Grey-Ash group, known here locally as the Mortimer Coal, the equivalent of the Tuscarora or Palmer bed—the same, in all probability, with the Coal F of Tamaqua, there the next in order above the true White-Ash group.

Fig. 159.—Section of the Basin C, at Tucker's Slope, head of Tuscarora Creek.—1 *inch* = 400 *feet.*



At a considerably higher level this Palmer or lower Grey-Ash coal almost emerges to the day at the mouth of the Palmer Tunnel (see Section of Tunnel), the Bony Vein, or next higher coal, being that which is there denuded at the axis. Advancing to Swift Creek, the Palmer or lowest Grey-Ash coal is found elevated high enough above a considerably higher water-level to be in its turn denuded, and to have its two outcrops separated to the two flanks of the anticlinal ridge. Finally, in the gorge by which Big Creek flows across the end of the main ridge of Mine Hill, the upper coarse beds of the great Seral conglomerate, at the base of all the Coal-measures, are elevated above the stream a height of more than 100 feet, but above the water-level at Tamaqua a height of several hundred feet. Adding the difference of level between the axis at Big Creek and at the Little Schuylkill to the positive thickness of the coal strata lifted out to the surface between the latter and the former spots, we discover an actual rise of the axis-line of this anticlinal, in a little less than 6 miles, of at least 1200 feet. West of Big Creek the axis continues slowly to ascend, spreading, of course, the outcrops of coals on its two flanks wider and wider asunder.

Fig. 160.—Section of Palmer's Tunnel near Tuscarora S.

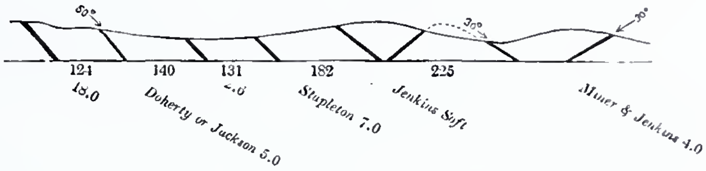


Basin C.—Of the basin between this anticlinal C and the S. side of Locust Mountain, there is nothing appropriate to add in this place to the information embodied in the Sections of the vicinity of Tuscarora. Its structure at Tucker's Slope, and in the Palmer Tunnel, are there correctly shown. In a theoretical point of view, the peculiarity in the flexure of the Grier Vein in Tucker's Mine is interesting, as displaying, by means of actual mining, a bulging upward of a concave into a convex fold of the roof and coal, a structure which, we are fain to believe, must exist on a large scale very abundantly in similar closely-compressed synclinal bendings, where sets of strata of unequal hardness and softness are, from the absence of crushing and sliding, unable to conform themselves, without this species of folding, to the reduced space into which they are forced.

Axis C *and* C C *near Tuscarora.*—South of the important anticlinal of Mine Hill above described, there occur in the vicinity of Tuscarora two saddles of inconsiderable length, and of subordinate influence.

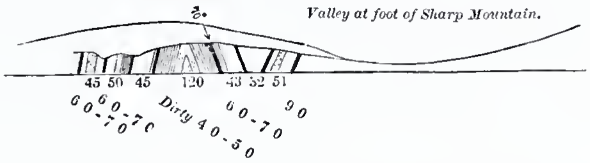
The more Northern of these issues from the ridge S. of the valley, embracing the watershed between the Wabash and the Schuylkill, and, crossing the latter, it enters the hill on which the village of Tuscarora is seated, passing a little N. of the main street, and S. of the Palmer Tunnel Coal-Breaker, W. of which meridian it is not at present traceable, through a deficiency of exposures. It would seem, however, not to prolong itself far. This axis has been proved by mining in the E. end of the hill supporting Tuscarora. It there appears as a saddle of very limited width, undulating a Red-Ash coal which is called the Jenkins Vein, in the middle of the wide basin formed by the South-dipping strata of the anticlinal C with the North-dipping beds of the saddle, C C, which passes through the hill to the S. of the village. This Jenkins Coal, thrown thus into two small subordinate basins, is apparently the second bed above the coal, better known at Tuscarora as the Jackson Vein, the precise relation of which to the Grier has never been determined.

Fig. 161.—Section of Red-Ash Coals E. of Tuscarora, looking E.
1 *inch* = 400 *feet.*



The more Southern of the two short Tuscarora saddles occupies the crest or rather the S. slope of the spur or hill immediately E. of the railroad, and next N. of the valley at the foot of Sharp Mountain. This little ridge extends not more than a fourth of a mile E., and the whole topography intimates the early cessation of the axis in that direction. Nor does it appear to possess a much greater prolongation Westward. We can trace it through the hill on which the Tuscarora Church stands, and may discern faint traces of it on the Palmer Tunnel branch railroad W. of this; but that is all: we lose every vestige of it further West.

Fig. 162.—Coals, E. end of Church Hill at Tuscarora.



There are four coals on the N. of this axis, all dipping at a very high or nearly perpendicular angle. They are all of them Red-Ash coals, and are therefore as high in the series, at the least, as the Stapleton and Jenkins beds, which lie next above the Jackson Coal. This axis, though seemingly so short, is a very closely compressed one, even its S. dip being as steep as 70°. It is evidently, however, not a broad saddle, for within 150 feet of it, on its S., there is a synclinal fold or trough bounded probably by the anticlinal which passes S. of the Tuscarora Church Hill, and not by the North-dipping strata of Sharp Mountain.

Anticlinal C C C *of Tuscarora, probably Axis* D, *or that of the S. Ridge of Mine Hill.*—There is an anticlinal to the S. of the Tuscarora Hill, not visible in the low grounds of the Schuylkill, but the N. dips of which form the bluff in which the hill S. of the church terminates, and are visible in the lower cuttings of the Palmer Tunnel railroad. This anticlinal has been detected in Chadwick's Mine S.W. of Tuscarora, his coal-bed saddling over the axis at a short distance up in the schutes above the water-level gangway. What coal this is which it elevates it is at present impossible to determine, but it evidently must hold a place rather low in the Red-Ash series.

From the position and direction of this axis, I am disposed to consider it the E. prolongation of the very important and interesting anticlinal of the S. ridge of Mine Hill, or that which has been designated by the letter D. The paucity of exposures and of mining developments between the vicinity of Chadwick's Mine and the Whitfield Tunnel, where we first fall in with the indisputably recognisable axis D, is probably the sole difficulty in the way of our perceiving this continuity. In any view, we must regard this as the next leading axis S. of the anticlinal C which passes N. of Tuscarora, and therefore the whole belt between them, nearly two-thirds of a mile wide, may be best considered as one general synclinal tract embracing the lower Red-Ash and the Grey-Ash coals, and undulated centrally by usually about two parallel saddles—those, namely, of Tuscarora ; for it is quite probable that, between the Palmer Brook and Big Creek, other corrugations of the strata similar to those of Tuscarora, though not strictly prolongations of them, may set in and expire before reaching the last-named stream.

It must be obvious, from all that has been here disclosed of the structure of this abruptly-undulated belt of country, that some of its outcropping coal-beds must exist in a very crushed and faulty condition—and this is what experience would seem to indicate ; yet other seams of a sounder character have been profitably mined here, but on a moderately small scale. This synclinal range includes the South-dipping coals opened and partially mined on Big Creek and its Eastern Branch to the S. of the Mine Hill saddle. Like the small anticlinal flexures N. of it, its N. dips occupy but a narrow space, and it may therefore be viewed as but a roll checking for a few hundred feet the long succession of S. dips prevailing from the main axis C of Mine Hill to the basin at the foot of the Sharp Mountain.

The Short Saddle D.—This flexure, which, by a little latitude, may be classed as one of the Tuscarora group, lies, by estimation, about 1000 feet to the S. of the preceding. It is that which bounds Chadwick's Tuscarora Basin on the S., and by its sharply-compressed fold inverts, or, at least, lifts to a perpendicular position, the two coal-beds and their embracing rocks visible just N. of Chadwick's small breaker. The place of the crossing of this saddle by the Pottsville carriage-road is detected in the vertically-dipping slates seen on the roadside, but W. of this intersection, and E. of Chadwick's Breaker, we have failed, from the obscurity of the ground, in all our efforts to follow it.

Carter's Slope.—This recently-established mine, a short distance N.E. of the village of Tuscarora, is in what is called the Jackson or Doherty bed. The coal dips 60° S. ; its thickness is about 8 feet, but only a 3-feet layer near the middle of it was good coal at the time of observation (1853). The bed was faulty in the first gangway leading off from the Slope 100 yards down ; a tunnel from the foot of the Slope 75 yards S., cuts the Stapleton Coal, but finds it faulty, and from 9 to 11 feet thick.

(For a view of the improved Coal-Breaker and Slope-house at this colliery, see the sketch given in one of the Plates.)

CASCA WILLIAM.

Axis of Sinnickson's Slope, or Anticlinal D.—Tracing the lower White-Ash coals from Silver Creek eastward to Casca William, the outcrop of the big Egg-conglomerate which underlies the lower White-Ash coals is found passing more and more N., or behind the flank of the valley, until it takes its place far enough N. of the Big Coal of Casca William Tunnel to prove it to be the Mammoth Coal. The same view was confirmed by retracing the ground, for the conglomerates N. of the Mammoth Coal, on the N. side of the valley, were seen, one after another, passing down with a sensible degree of Southing in going Westward, as if turning to basin. I satisfied myself that the axis N. of Chadwick's is that of Sinnickson's Slope. The arch is visible at the head of the hollow E. of Silver Creek Valley. Chadwick's Coal rises flattening upon the conglomerate, and Guiterman's Coal also flattens towards its outcrop under the same rock. I next traced the same anticlinal Westward from Silver Creek. It evidently holds its cover through the high flat summit of the ridge, and the upper Egg-conglomerate is seen in its S. dip all the way to the head of Windy Hollow, and past the head of Zachariah's Run, a little E. of which meridian the axis may be detected in more than one place in the rocks between this S. outcrop of the conglomerate and a ridge to the Westward answering to that at the head of Silver Hollow. This latter runs into, or nearly into, the bold flank of Mine Hill N. of Johns Coal. The deep cove behind the upper and lower White-Ash large coals evidently contains this anticlinal, for it is directly in its line. This hollow is indeed an excavation in the N. dip of the arch, seen in both dips at Johns dirt-heap, and also in the synclinal N. of it. The summit of the arch formed by the upper Egg-conglomerate is well seen in sundry places N. of the road on the ridge leading towards the reservoir. All the features of the topography and all the courses of the axes and of the outcrops confirm me in my view, that the Johns Coal is inferior in position to the Milne's or Mammoth Coal of Mill Creek. The lower large coal (Johns) is said to rise to the surface, or near enough to outcrop in the middle of the arch a quarter of a mile E. of the breaker, where the lower small coal and attendant rocks evidently reach the surface a little more to the W.

Coals in Basin D F, on Casca William Creek, in ascending order :—

1. *Big Vein* is the same as the Big North Vein of Silver Creek, as is proved by a line of air-shafts sloped upon it ; dip 61° S. Its average thickness is about 18 feet ; the gangway on its lower level has been driven 1000 yards to the W. ; it is sometimes called the *Raven* bed.
2. *Black Heath* (S. of Tucker's Silver Creek).—In the tunnel 28 yards S. from the Big Vein. The length of gangway is about 500 yards. Between Black Heath and Big Coal is a pebbly rock ; this is a Grey-Ash coal, 10 feet thick, with dip 60° S.
3. *Black Valley* is S. of the Black Heath 14 yards ; it is 7 feet thick ; it dips S. 55° ; its ash is grey, verging on red. The gangway is driven about 675 yards to the Westward.
4. *Brayler* Coal, 2 feet thick ; Red Ash ; S. of No. 3, 112 feet ; it dips 50°. Its gangway runs about 130 yards.
5. *Wright's* Coal is 8½ feet thick ; Red Ash ; very good coal ; 111 feet S. of No. 4 ; dip 45°. It has no gangways ; four shafts.
6. *Pasco* Coal is 8 feet thick ; dip 30° S. ; it is 400 feet S. of No. 5. No drift.
7. *Lyon's* Coal has 5 feet of good Red-Ash coal ; it is 63 feet S. of No. 6, and the 3d under the Luther.
8. (*Coal not named*), No. 3 of tunnel ; is 7 feet thick ; it has 4 feet of good Red-Ash coal ; it is 87 feet S. of No. 7. The gangway extends about 250 yards.
9. *Diamond* Coal, No. 2 of tunnel ; average 4 feet ; not extensively proved here ; the North Diamond of Neill on Silver Creek. It lies 48 feet S. of No. 8.
10. *Luther or South Diamond—the Red-Ash Slope Coal.*—Its average thickness is 5 feet ; its dip in the slope is 50°, but it is flatter on the same level further W. It has a gangway worked Eastward on its S. dip below water-level to the Hubley Tract. They have worked it up to the line of Bushy Tract.

In the N. tunnel there is a leader, 15 feet N. of the Big Vein, measuring from 1 foot to 18 inches in thickness. The Skidmore Coal is 47 feet N. of the Big Coal.

Basin D F, from Sharp Mountain to Silver Creek, or Patterson Basin.—This basin, running off Westward obliquely from the N. flank of Sharp Mountain, is throughout its length to Silver Creek, and indeed beyond it, undulated by at least one subordinate anticlinal flexure: thus the axis D disturbs it in the neighbourhood of the Schuylkill and Swift Creek, and the longer anticlinal E divides it into a wide and a narrow trough between Casca William and Silver Creek. The Big White-Ash coal just reaches the surface to turn abruptly down again on its North-bounding anticlinal at the Sinnickson Slope on Casca William; but this nowhere else appears along its N. border, even the lowest of its South-dipping beds belonging to the Grey and Red-Ash groups. On the S. side of the basin those dipping N. from its bounding anticlinal F are the Red-Ash coals just under the Peach Mountain Vein, but these belong only to the S. half of the trough, for at Casca William, and probably E., certainly E. of Brockville, these upper Red-Ash beds are lifted out—not to re-enter the ground again—by the anticlinal flexures D and D. The engraved Section of the Casca William Coals will make this more obvious.

The principal mining operations embraced within this belt are Beachem's Mines S. of Tuscarora; mines on the Schuylkill N.W. of Beachem's; the De Long Mines of Whitfield Lower Tunnel; the Upper Bushy Mines; and the Red-Ash and White-Ash collieries on Casca William.

COLLIERIES AND COALS—SHARP MOUNTAIN COLLIERY.

Beachem's Tunnels.—The length of the Western or *Lower* Tunnel is not positively known, but it is about 120 yards. It cuts four veins, one of which is faulty, and not wrought.

1st vein from the mouth is 4 feet thick.
2d „ „ „ 6 „
Sometimes 8 feet Pink-Ash coal—2 benches, 6 feet and 2 feet.
3d vein from the mouth is 6 feet thick—dirty.
4th „ „ „ a thin leader.

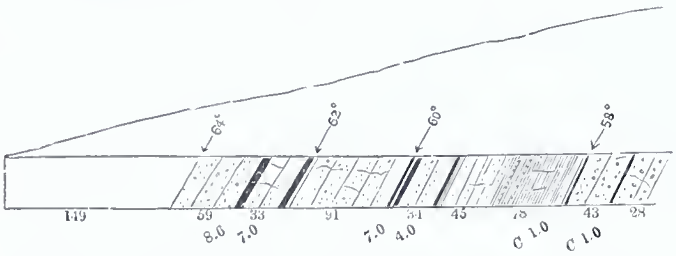


Fig. 163.—Beachem's Tunnel entering Sharp Mountain S.W. of Tuscarora, looking E.—1 *inch* = 200 *feet*.

From the second to the inner end of the tunnel is 80 yards, and it is about 40 yards from it to the mouth. The distance from the second to the third is about 25 yards. The tunnel ends in white Nut-conglomerate. The pitch of all these veins is about 60°.

The gangway on the Eight-feet coal of the Lower Tunnel has been driven W. 1200 yards; it was also driven 200 yards E. By shafting, this coal has been proved to continue through the Coal-hill estate, making the whole distance 1½ miles.

The Eastern or Upper Tunnel is rather more than 900 yards E. of the Lower, and the level is 40 feet higher. Its length is 600 feet, and it cuts five coals. (The numbers of the coals in the two tunnels express the same coals according to the idea of the proprietors.)

The first coal is about 100 yards from mouth of the tunnel; where struck, it is about 5½ feet thick. In the gangway it grew thicker, say 12 feet. It is mostly a dirty faulty coal.

The second vein—the rough vein—has the coal quite soft, and too rough to be saleable: its thickness is 2 feet.

The third vein is about 4 feet thick; it is hard, but too rough to be saleable.

Ten yards to fourth vein, 140 yards from the mouth of the tunnel; contains some good coal, 5 feet thick; it dips 60°; is in two benches, one 3½ feet, the other 15 to 18 inches—pink ash.

The gangway E. on the Five-feet coal (in the Upper Tunnel) is driven about 500 yards. The Upper Tunnel cuts two thin coals or leaders, the S. of which is 60 yards further than seam

No. 4, which is the one worked. It consists of 2 feet of hard bony coal, with about 7 feet of black slate underlying it.

BUSHY VALLEY.

Bushy Tract is bounded on the S. by the N. line of the Woodburn Tract. The compass-line along Bushy Railroad, from the head of the railroad on the axis-line at the Old Breaker Schute, is—

S. 30° E.—98 feet to Spring Coal overlaid by sandy slates; dip S. 50°; coal about 6 feet thick.
+ 83 feet to Ravine Coal, 3 feet thick; dip 50° S.
+ 68 feet to local Lewis Coal, 5½ feet, sometimes runs up to 12 feet, of good coal, Red Ash; dips from 40° to 50°.
+ 283 feet to dirt coal, 5 feet thick.
S. 18 E.—250 feet to 3-feet coal.
336 feet to a 2-feet coal—pretty good quality.
S. 4° E.—480 feet to Adam Stahl Coal.
Thence to Peach Mountain Coal.

From the axis at the brook crossing the railroad to the opposite schute of the Breaker is 1070 feet; the course is S. 4° E. The bearing of the chord below the Breaker is S. 12° E., distance 240 feet.

S. 38° W.—420 feet to the next turn of the railroad.
S. 22° W.—360 feet across the curve.
S. —180 feet to the Switch-back of Casca William Railroad. The N. dips of the quarry of sandstone and conglomerate are N. of Switch-back 180 feet. From this spot to Middleport the dips seem S.

There would seem to be an anticlinal in the tunnel of the Stahl Coal. This turn, which is the axis F, affects the Stahl. The dip in the gangway is about 35° S.; ascending, it becomes flat, and then descends in a counter-dip. The miners have sunk a perpendicular shaft on the top of the saddle, and found the rock horizontal, with shale and clay, and 2 or 3 feet of coal, fragmentary, and probably overlying the Stahl. The same thing occurred in an exploration some 50 yards further E. on the course of the bed. The vertical shaft is about 30 feet deep to coal a little S. of the crest of the saddle. On working a few feet N., the sandy slates were found level, and then rapidly turning down into N. dips. This is some 350 or 400 feet E. of the railroad. The drift-mouth of the Adam Stahl is to be placed at 480 feet from the small South-dipping vein.

On the W. side of the railroad the Stahl Coal is a sound good coal, from 4 to 7 feet in thickness. The axis shows itself as flattening, in rising, the breast in the gangway both to the E. and W. But the miners never drove over the anticlinal.

About 40 or 50 feet above the Stahl Coal is a coal about 3 feet thick near the outcrop. Its presence was proved on the W. side of the valley. 180 feet above this is another coal 4 feet thick, very clean and rich, but soft and shelly.

About 150 feet still higher is the Big Coal; it varies from 3 to 8 feet in thickness. In driving this, the dips were seen verging more and more to the E. as the gangway ran E. This Big Coal is the one opened at the crest of the hill on the road to Catawissa.

About 130 feet above the Big Coal comes the Slope Coal, which at the Slope dips about 20°, and steepens below. Its direction is nearly N.E., and its thickness is about 2 feet. It thickens and thins on successive swells.

The anticlinal would cross the railroad a little S. of the Breaker. The stack of the Breaker is about 350 feet from the railroad in a perpendicular line.

The anticlinal axes on Bushy Creek are—

1. That at head of Bushy Railroad.
2. Bennett's Northern axis a little N. of the gangway of the Adam Stahl Coal.
3. Bennett's Southern axis a little S. of Breaker, &c.
4. The axis which crosses the railroad near the fork.

Meyer's Tunnels on Bushy.—The lower tunnel cuts through greyish-ash coal. The head of this tunnel is near the anticlinal D. The last coal cut is the Spring Coal, the first is the Lewis Coal. The tunnel also cuts the local Lewis, Ravine, and Spring Coals.

The upper tunnel cuts two coals—1st, a soft coal 2 feet thick; the 2d, about 6 feet of worthless coal-dirt. The distance between them is about 30 feet, the dip about 75°.

Meyer says that the second vein on the N. of the axis of the Red-Ash mines, on Hubley Tract and Casca William, is the same as the second which he found on the N. side of the Bushy axis.

It is possible that one or more veins may occur between this axis and the mouth of the tunnel, but none have yet been seen besides the two which lie directly on the saddle.

Mr Meyer ran a drift on the second vein N. of the anticlinal about 300 feet; the dip was 45° N. The coal S. of this is much steeper than this, and steepens as it descends. The second vein appears to split, and the N. part of it runs off with a gentle dip, both dipping N. This lessening of the dip N. of the axis favours the idea of a second axis S. of the Upper Tunnel, as at Casca William. North of this second coal there is a blank (a swampy valley), where no dips appear, but where the second axis may come in.

The slope on Bushy at the Breaker dips N.E. 35°, and the gangway seems to turn to a more Easterly dip, indicating the W. end of the synclinal. The rock which crops out on the road from beneath the basin at the anticlinal axis on the S., looks very like the underlying rock of the Peach Mountain Seam.

The Luther or South Diamond Coal of Casca William is the second N. of the Lower Breaker, and first S. of the Ravine: it is worked through, and dips about 55° to 60°. It varies, and at Casca William is in steps. The seam is a clear good Red-Ash coal, 5 feet thick, and has a strong rocky 2-inch slate in it.

Basin F H, or that N. of the Peach Mountain Basin, from Sharp Mountain to Silver Creek.—This basin, commencing in the flank of Sharp Mountain S. of Brockville, and extending to Silver Creek at Quigley's Hollow, contains few or no extensive collieries: this circumstance is evidently due to its geological structure, which is that of a much-compressed obliquely descending or folded synclinal trough. Excepting the Peach Mountain basin S. of it, it is perhaps the most oblique or inverted basin in the coal-field. A glance at the Casca William Section will make this obvious to the reader: it shows three South-dipping folded troughs in the N. half of the basin (the Peach Mountain Basin,) the most S. being the most squeezed, and this one next. Being bounded both N. and S. by a folded anticlinal, it is obvious that its coal-seams, all of which belong to the readily yielding and soft upper Red-Ash Coal-measures, must be very generally in a crushed and bruised condition; and we cannot, therefore, be surprised that this, and the belt S. of it, have for so many years disappointed all efforts at the erection of permanently productive collieries. It embraces almost precisely the same coal-seams which are included in the Peach Mountain belt; only the Peach Mountain Vein itself, the uppermost in each basin, occupies a shallower and narrower trough. This identity of the central uppermost seam with the Peach Mountain bed, so clearly established by our Section, was long ago shrewdly conjectured by one or two of the practical miners of the neighbourhood, who have laboured long but fruitlessly to make these Red-Ash Coal-measures productive.

Basin H I, or Peach Mountain Basin—Sharp Mountain South of Patterson.—This village is itself in basin *D F*, but at the railroad station there is a good exposure of slates dipping S. 20°, and in the hill on the S. flank of which these dips occur, there is evidently a synclinal axis lying S. of the railroad. At the E. end of the village there is a very steep N. dip in the slate. That there is a basin in this narrow-necked hill is proved by shaftings as well as underground mining. Indeed, the Palmer Vein gangway is worked round the end of it.

Milford Colliery, Peach Mountain Basin, Tunnel and Slope.—The slope is 132 yards down on the so-called Clarkson Coal, and 100 yards below the old water-level gangway; the breast is about 90 yards; the dip at the top of the slope is about 57°, at the bottom it is 42°. This coal-bed has been driven E. and W. from the bottom of the slope for more than 300 yards; the average thickness is 5 feet of good coal; there are occasional slate and bony partings; it varies from 2 to 6 feet, and has a covering of rotten slate from 1 to 3 feet thick. A tunnel is being driven (1853) from the bottom of the slope on the Clarkson Coal, S. to the Charles Pott Coal. The Clarkson is N. of the Charles Pott on the outcrop about 400 yards. The tunnel is 450 yards long. It starts at the Charles Pott Coal, and runs across the measures until it strikes the Palmer in S. dip. It then runs along the Palmer to the Eastward for 440 feet, and is then tunneled again. The actual tunnel-length is about 303 yards.

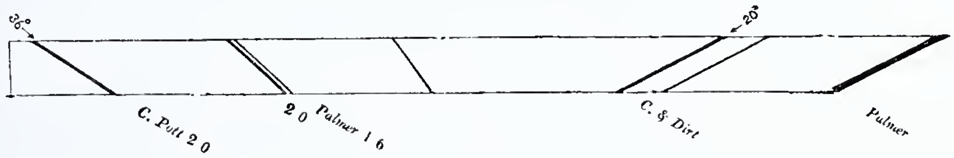


FIG. 164.—Milford Tunnel.

The Palmer Coal is worked on its N. and S. dips E. of the tunnel. The range of the N. dip of the Palmer Coal is in the N. side of the hill, that of the S. is in the S. side of the hill; the basin lies in the ravine, 270 yards S. of the tunnel's mouth. The breast of the South-dipping Palmer Coal is 64 yards, and the North-dipping is 58 yards to an upper level, thence the same distance to the outcrop. The dip of the North-dipping Palmer Coal is nearly vertical, but the dip of the N. part of the coal is S. about 15°—not enough to run the coal down the breast by gravity. The N. and S. gangways have been gradually turning, until now they come together, thus making the end of the basin.

The Palmer Coal contains about 2 feet of very solid coal.

The Charles Pott Coal is also about 2 feet in thickness.

The most Southern coal cut in the tunnel is about 52 yards S. of the North-dipping Palmer. This coal is by some thought to be the Charles Pott Coal, but the Superintendent considers it identical with the leader cut N. of the South-dipping Palmer.

The dip of slaty sandstone at the foot of the breaker of Milford Tunnel S. is about 45°.

The coals worked by Billy Wall at Middleport—that is to say, the two N. coals—are the same as the N. dips of the Charles Pott and Palmer Coals, while the coal worked by O'Brian is still S. of the Milford Tunnel, and there is a drift on it in the brook S. of the end of the tunnel. The Superintendent says that he has shafted a coal on the second or N. spur of Sharp Mountain: he thinks the upper of this series are the same as those worked in Beachem's Tunnels.

The Clarkson Coal on the S. dip enters at water-level below the breaker, and has been worked E. about 1100, 1200, or probably 1300 yards, as far as the farmhouse S. of Patterson. There is a gangway in the old field E. of the farmhouse; here the outcrop passes N. of the house. Generally this coal has a gentle S. dip, but at the N. end of the slope it is about 55°. About 25 yards below the water-level in the slope there is a rock-fault, with a sudden upcast of 25 yards; it entirely cuts off the coal without even a leader: this is an unusual thing in this coal-basin. The Clarkson Coal is worked by Billy Wall at Middleport.

The *Charles Pott* Coal at Milford is entered by a drift just at the mouth of the tunnel; the dip is 55° S. The slates outside show a dip of 35° or 40° from hill-side pressure. It contains 2 feet of good hard coal, having rock at the top and slate at the bottom. It was worked nearly as far as the Clarkson, but in the tunnel it was mined only 15 yards each way. It was worked to the E. by Dr Steinberger, and at Middleport by Billy Wall.

It is believed that the Palmer Coal has both a N. and S. pitch on the Milford property S. o Milford Colliery.

Peach Mountain Basin traced from Bushy Valley westward.—Started from the quarry on the N. side of the anticlinal, near the junction of the Casca William and Bushy Valley Railroad, we may trace the axis on the S. side of the Peach Mountain synclinal over to Lick Run.

If followed by air-holes, the first S. dip next S. of the North-dipping rocks, brings us out S.E. of Thompson's house, at an exposure where the anticlinal is well seen. Following the strike with care, it leads into the road, to the right of which are shafts which run on to the Peach Mountain Coal of Lick Run. There therefore remains no doubt of the continuity of the Peach Mountain Basin from above the Casca William Fork to Lick Run. Mr Murray of Lick Run says that the Peach Mountain Coal had been wrought on both sides of the valley on both dips, the N. dip being nearly vertical, the S. comparatively gentle.

Middleport Synclinal Belt, or General Basin between the Anticlinals I *and* K.—After the general description which has been given of the broad and undulated trough enclosed between the Peach Mountain anticlinal I and the Gate Ridge and Silver Hill axis, it seems unnecessary, in the present imperfectly-opened state of this ground, to attempt a minute systematic description of it. Indeed, nearly all that is specifically known with regard to its coal-beds will be found assembled in the details now to be appended of the several mining localities which it embraces. If these are carefully perused in connection with the Sections, the reader will be in possession of nearly all the data accessible for a further tracing of its numerous valuable but much twisted coal-seams. It may be well, however, before entering upon these details, to call to mind the fact, that the whole of this belt, but especially its S. half, or that between the river and Sharp Mountain, is much contorted, and that it is not possible, with our present knowledge of its saddles, to subdivide it into continuous basins. The only regular basin which traverses the belt is that which extends through Middleport from Sharp Mountain to Silver Creek, near New Philadelphia, and the synclinal axis of which I have named *ff, fff*: this, it will be perceived, lies many hundred feet N. of the range of the great Norwegian synclinal of the N. foot of the Gate Ridge which passes through Cwmbola and Belmont. Adverting to the coal-seams embraced in the division of the belt E. of Silver Creek, they would appear to belong to the very uppermost group of the Red-Ash series, or that including the Peach Mountain and Spohn or Lewis beds. A reference to the Casca William, Silver Creek, and other sections, will make this immediately apparent, and will show, moreover, that while the Peach Mountain Basin, so called, N. of axis I, contains but a very narrow trough of the seam of that name, this wider and less-folded belt possesses a much ampler and deeper basin not only of that coal, but of the locally-called Palmer Vein below it, and of the Spohn Vein above.

Middleport.—Coals of the Spurs E. and S. of the Town.—There is an anticlinal in the ravine at Lawrence and Brian's Old Colliery. There are here five coals, four of them mined, and all Red-Ash beds.

a. The first bed is worked out above water-level, and is not regular: it is sometimes 7, 8, or 12 feet in thickness, or even as high as 15 feet, and as low as 5 feet. It is called the Big Coal Vein. The gangways run 600 yards to the E.

b. There is another bed 60 or 70 yards N. of the Big Coal; it is sometimes called the Gate: it has about 4 feet of coal, generally regular. The dip is 45° N., but steeper near the W. end of the hill. It is clear Red Ash, and good coal. The gangway runs 700 or 800 yards E.

c. Bed 4 yards N. of *b*; has on it a gangway 100 yards to the E. It has Bone coal 4 feet in thickness, and in the shaft on the hill it has 4 feet of good coal and 3 feet of Bony coal. It dips steeply N.

d. Is 60 yards N. of *c*, contains 3 feet of coal; it has been worked through the hill. The dip is steep to the N.

e. Is 8 or 10 yards N. of *d*; its dip is steep to the N., and it has 6 feet of good coal, now in fault. It has been worked 300 yards E. These two will probably enter the Milford Spur, while the other three will range S. of the ridge, and enter S. of the farmhouse.

Shaftings and Tunnel S.E. of Middleport.—There is a steep S. dip on the railroad at Middleport. The coal is worked by Larry O'Brian. S.E. of Middleport is the "Big Gate," with steep dip N.

Dr Steinberger, the proprietor, thinks it the N. pitch of the bed which at Milford is worked on the S. dip. The coal and adjoining rocks are much alike.

Passing S. across a ravine, we come upon the Palmer Coal with quite a steep N. dip. Dr Steinberger has traced four beds around the E. end of a synclinal by his shafts. S. of this are N. dips for some distance, forming the N. side of the anticlinal lying S. of the above trough. There is a 10-feet coal N.W. of the tunnel, on the S. side of the ravine. The dip is very gentle to the S. The course of the tunnel is S.; the length is 420 feet; it cuts only one vein at its far end, which is 10 feet thick, and contains 6 feet of good coal; the dip is nearly vertical. N. 315 feet from the tunnel is the shaft of

Coal No. 1. The bearing of the tunnel is S. 19° E.; the dip of the coal is 36° S.; over it is Nut-conglomerate. There is a stream 40 feet from tunnel, and 280 feet to the foot of the ridge.

Coal No. 2. is 490 feet from the tunnel; its dip is 36° S.; it is 14 inches thick.

Coal No. 3. is 680 feet from the tunnel, the dip as above; it has 22 inches of coal. N. of this is the anticlinal. The distance from the tunnel to the first N. dip is 1190 feet.

Coal No. 4. There is a lower coal very thin on the S. side of the anticlinal; it has been followed round by shafts, and found out to be the fourth coal of those dipping N. on the other side of the axis.

General Beckel's Tunnel, S. of Middleport, is 140 yards long; it crosses the strata to the S. in the N. side of Sharp Mountain. This is what at present is called Dado's Tunnel; it was wrought by Neville.

Neville's Mine, S.E. of Middleport.—The coals have been shafted around an anticlinal axis next S.W. of the hill of Milford Tunnel. The basins N. and S. of Silver Hill and the intervening axes are proved by Dr Steinberger's shaftings. The next axis is proved by topography, and the dips of the strata on its N. side. There are therefore three anticlinals S.W. of the Milford Tunnel Hill, combining to form the broad shoulder of the Sharp Mountain near Middleport. A line of outcrop extends from the Lower Beachem Tunnel, about 2 miles to the E. The turn of the S. basin is about 800 yards E. of Dado's Tunnel. Neville works a large coal in the New Tunnel, on the axis next N. of this basin of Dado, and also works it in the Dado Tunnel.

It has been supposed that the range of the shafting, &c. in the Eight-feet Coal of the Lower Tunnel would lie in a curve towards Middleport S. of Milford Tunnel Hill; but as that curve reaches round to Steinberger's Basin, the exact course is uncertain. Possibly an anticlinal comes out N. of the basin in question, which will make the curve not a blunt, but a somewhat more sharply-looped one.

Steinberger's Mines, half a mile S.W. of Middleport.—Near the valley of the railroad, Dr Steinberger is working the tunnel coal from 5 to 6 feet thick. He has driven his tunnel 80 yards (October 1853), and has cut three veins. The tunnel is driven S. The Gate Coal is drifted on N. of the mouth of the tunnel. Dr Steinberger is about putting a slope upon it. The first coal in the tunnel is 40 yards from its mouth; it measures 5 feet in thickness, but half of it is Bony. The second coal, 7 yards further on, is a good coal, from 3 to 4 feet thick. The remaining 33 yards, at the back of the tunnel, is not usually good; the coal is in fault, but when it is good, it is 5 or 6 feet thick. All these beds have a nearly vertical N. dip.

COALS AT MIDDLEPORT.

The *Clarkson* Seam at Middleport was opened and identified by Mr Thompson; its dip is S.; it contains 3 feet of coal and 3 feet of dirt, Bone Coal, and slate-top. It was shafted E. to Milford Colliery.

The *Charles Pott* Coal is 2½ feet thick, and faulty at Middleport. Havener worked it on its S. dip W. of Middleport, but the coal was not good.

The *Palmer* Bed varies from 20 inches to 2½ feet of good coal. All the S. dip was worked on the N.E. side of Middleport by Patrick Freeman on Hensinger's property.

The *Little Tracey* Coal has been shafted W. of Middleport; its dip is S.; its thickness 2½ feet; it has under it a coarse Nut-conglomerate.

The *Peach Mountain Vein* at Middleport is from 2½ to 4 feet thick, with a fine leafy roof and a slate bottom. This bottom-slate is 7 feet thick, and under it is a small rough bed, which looks like "baked bread:" it has no grain or lamination, but is like "twisted dough:" the coal is good, and of a rather pinkish Red Ash. The Peach Mountain Coal has the usual parting-slates, always recognisable, but here they are thin. The small underlying coal is well known at Pottsville. It has 1½ inches in thickness of a dull coal, like coarse cannel-coal, for its top ply, both at Middleport and Mill Creek. The Peach Mountain Coal is worked as far as Silver Creek.

The *Spohn* Coal at Middleport is worked by H. Uren; on its S. dip it was from 6 to 7 feet thick, and when faulty, declined to 2 or 3 feet. It had the same roof and slate as at Belmont (Five Points) and Centre Turnpike.

COLAHAN'S GATE VEIN COLLIERY.

Colahan and O'Hannan's.—There is an anticlinal axis well exposed in the bank on the side of the river, from which axis the centre of the railroad bridge is distant about 100 feet. S. of this is another axis, and the basin between them has on its S. side perpendicular and inverted dips. The Perpendicular Coal, here worked by Colahan, is said by him to be the *Gate* Vein, but in the existing imperfect state of development of this much-undulated belt, from Silver Hill to the true Gate Ridge, it is premature to pronounce upon an identity so doubtful.

Coals—Big Gate Bed.—At this, the first place where it was discovered E. of Pottsville in the year 1845, the dip was perpendicular: it was worked entirely above water-level: it had 300 feet of breast: its gangway extended W. 600 yards, and its thickness was from 10 to 12 feet from slate to slate. The intermediate slate varies from 2 feet to 16 inches in thickness: both benches are worked, the N. being of an average thickness of 6 feet—the S. bench was from 2 to 2½ feet thick. The coal was not very solid.

In the N. dips, lying N. of the Gate Coal, two veins have been proved. The whole section shows—

1. 21 feet N. of the Gate Coal a small vein 3 feet thick. It was worked by Preston half a mile W. of this, where it was 5 feet thick. Here it was worked 200 yards, and became faulty. About 3 feet S. of it is a regular band of iron ore in slate.
2. 40 yards N. of this a faulty bed 3½ feet thick. It has been shafted at Preston's; it proved at Havener's to be good for nothing. Its crop is near Colahan's present Breaker. The S. slate is very reddish and shaly; the N. slate is a tough or bony rock.
3. 64 feet N. 51° W. from the end of the Breaker there are about 3 inches of a somewhat pebbly sandstone with perpendicular dip; N. of this the measures are slightly more inverted; at 150 feet it has a strong N. dip, and at 175 a dip of about 35° N., in a soft shaly rock. A thin seam occurs here, but its thickness was not proved; the dips were fast flattening. It was 250 feet from the Station.
4. In a direction N. 32½° W., measuring 193 feet to the centre of basin, the dips continue flat. A vein, not proved, is here supposed to be at 150 feet on this course.
5. N. 9° 10′ E. 215 feet brings us to a small 3-feet coal; the dip is S. about 45°.
   At 315 feet is the centre of the *anticlinal.*
   At 360 feet is a small North-dipping coal, and at 415 feet is the W. abutment of the railroad bridge.

Section South of the Big Gate Coal, course S. 56½° E.—At 100 feet, conglomeritic sandstone: 260 feet to *Little South Gate;* coal 5 feet thick, but variable; at one time it measured 25 feet, with perpendicular dip. The Bone Coal is on its N. side, and the black slate on its S. side. 25 feet further S. is the *main South Gate.* Its average thickness is 7 feet. The upper and lower slates are perpendicular, like the preceding.

120 feet across the strike is another *South Gate.* Across the strike, 180 feet S. from this, is what Mr O'Hannan thinks is the *Selkirk Coal:* it has been shafted, but is not worked; dip perpendicular; average thickness 7 feet; bony slate on N. side. Layer of slate about middle, one foot thick. About 100 feet across the measures from this is a 3-feet vein, faulty dip S. 50°: 169 feet further is a 2-feet coal called the Small Vein, dip perpendicular, 20 feet thick at outcrop; not faulty, but very variable; has been worked.

Axis further to the East.—About 200 feet S. of this axis is the *Black Mine Vein,* about 8 feet thick; 3 feet bottom bench; 4 inches undermining; 5 feet top bench; roof strong bony coal. From this Southward 75 feet is the *Tunnel Vein,* well shafted on; about 6 feet thick, two benches—much the same as the Black Mine. The Salem lies S. of this; it was shafted near Middleport by John McKachney of Tamaqua.

NEW PHILADELPHIA.

Preston's Colliery (*Neville and A. Lawton's*) *opposite New Philadelphia.*—In the year 1853, a slope was sunk some hundred feet S. of the breaker here. It is upon the Selkirk Coal, dipping S. 75°, now (Oct. 1853) sunk 60 yards. The coal varies from 8 to 14 feet thick, averaging 10 or 11 feet of good coal.

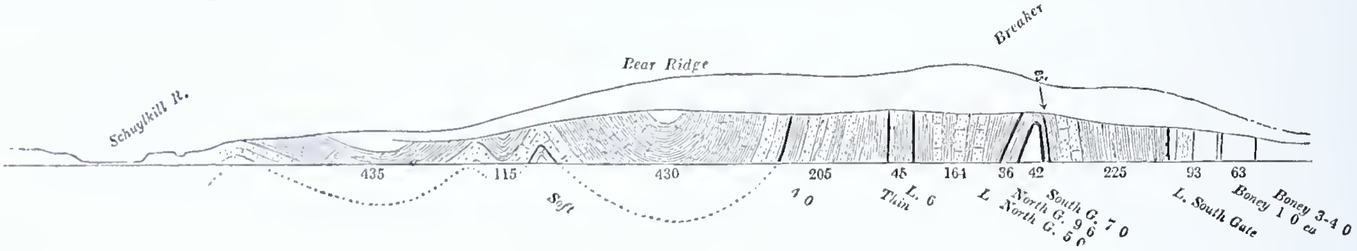


FIG. 165.—Section at Preston's (Neville's) Colliery off New Philadelphia, looking E.—400 feet = 1 inch.

Coals.—The first vein on which a gangway was driven on the W. of the creek contained about 2 feet of a coarse faulty coal; the dip was perpendicular: 22 yards to Northward of this are two coals separated by about 10 feet of slate; the S. one, with a gangway, contains 2 feet of poor coal; dip perpendicular: 31 yards N. to *Little South Gate*, has from 2½ to 3 feet of good coal; dips perpendicular 75 yards to *South Gate.* This has been worked four years on the E. and N. sides of the valley. On the E. side it was worked in 400 yards, when it ran into a partial fault. On the W. side there was a complete fault at 300 yards' distance; dip of the South Gate 85° S. The average thickness of the South Gate is 7 feet; the S. bench is 3 feet—divided by from 2 to 3 feet of slate. The N. bench has 4 feet of rather soft shelly coal; the S. bench is good coal, and outcrops on the surface of the hill; but the N. bench saddles 24 or 25 yards under the surface on the summit, and, turning down (according to Preston) by the side of the main or North Gate, makes from 12 to 14 feet of good pure coal with *no* bench.

Main or North Gate.—Has one solid bench of good coal, averaging from 9½ to 10 feet in thickness—in one place it is 19½ feet thick, and runs so for 8 or 10 yards; dip 85° N. The distance between the North and South Gate, at the gangways, is 14 yards on the E. side, and 21 yards on the W. side of the valley.

The measures on the E. and W. drifts are generally sandstone, with a good deal of iron ore, but for 15 yards S. of the Gate Coals we have soft slates.

About 12 yards N. of the North Gate we have the *Little North Gate.* It contains 4½ or 5 feet of good coal. The dip is 85° N., and parallel to the North Gate Coal. All these coals have from 60 to 70 yards breast. The North and Little North Gate mines were commenced in the spring of 1852.

John Preston's mine sends an average of 60 tons of coal daily to market.

There has within the past year (1852) been a slope sunk on the Selkirk Vein, S. of all the Gate veins: the dip is 75° S.

Lick Run.—The first coal of Casca William has been worked at Lick Run; N. of this is the Big Diamond, mined by Murray under the name of the Big Tracey. The working was probably on the S. side of the saddle; the N. dip is not seen. N. of this saddle is the comb or crest of conglomerate and sandstone, which has been traced from Casca William, and overlies the Adam Stahl. To trace this we ascended the comb of the hill, and followed it on the strike, having a series of shaftings on our right, or N. of the crest, and near it. These are on the coal seen directly beneath the conglomerate; N. of these again are Quigley's openings. The drift on Silver Creek is on the coal. Following the crest, we struck the road on Silver Creek 300 feet N. of the Spring Coal. The anticlinal of the *Spring* evidently lifts the same conglomerate. This, I think, is the axis between the synclinal of the Peach Mountain or Small Coal, and that of the Tracey or Big Diamond, which is the large coal wrought by Murray on Lick Run.

Mr Murray worked the Big Tracey on the S. dips of a coal, and proved the synclinal axis by driving, near the angle, 4 feet across into the N. limb. The distance of the outcrop, at the surface of the two dips, is 40 yards. He says that the S. pitch is very variable. Towards the bottom the vein swelled out to some 20 feet thickness. The thickness of the seam is very changeable. It contains some very firm sound coal, and some mere dirt. He thinks that the Stahl Coal is S. of the conglomerate, or between it and the Big Tracey. Thompson and others, as above stated, place it near and beneath the conglomerate, or correspondingly to the 5-feet seam proved by Murray. From the range of the Tracey it is 525 paces to the Southern edge of the conglomerate.

Immediately under the conglomerate we saw *Murray's Drift*, and 100 feet further N. another drift, and 60 feet further a third. On the E. side are two drifts, 150 feet apart.

Coals ascending Lick Run—

1. *Palmer* Coal, 3 to 3¼ feet thick; good coal; worked up to the line of the Barrow and Evans Tract. Dip 35° S.
2. *Charles Pott* Coal is the same in dip and quality, and has been worked by the same person to about the same limits.
3. *Clarkson* Coal is not worked here, there being a long blank space.
4. *Peach Mountain* synclinal coal, with N. and S. dips. It is entered by a gangway on both sides of the ravine. The S. part, or perpendicular dip, is from 4 to 5 feet thick, and the N. side with S. pitch from 3 to 5 feet. The coal is a good quality of Red-Ash anthracite, but very faulty. The Peach Mountain must be the same as the Charles Pott.
5. *Big Diamond* (so called). The drift on this bed is higher up the creek. It was worked by B. and W. Murray. The dip on the top of the hill is 35° S. The thickness of this coal ranges from 4 to 7 feet; it sometimes swells to 20 feet. Between Nos. 4 and 5 are two other coals which have not been mined.

CHAPTER VI.

COAL-FIELD BETWEEN SILVER CREEK AND MILL CREEK, ANTICLINALS, BASINS, AND COLLIERIES.

Flexures on Silver Creek.—For a clear conception of the structure of the coal-field on Silver Creek, the reader should consult the elaborate Section in Plate I.

Anticlinal Axes.—1. The axis of Guiterman's Coal, axis D, at the head of the open valley, is the same as that of Johns and Pinkerton, Mill Creek, and that of the Casca William spur.

2. The axis of Neill's N. Diamond Coal, axis E, is but a minor wrinkle on Silver Creek. It is highest or sharpest E. of Neill's on Silver Creek, and flattens and seems to die to the Eastward, for his gangway turns its E. part at the distance of 600 yards, and the gangway above the water-level also turns round W.

3. The next is the axis first S. of Neill's Breaker, and on the W. side of Silver Creek, in a small spur just S. of the lower road to Eagle Hill, or at Capewell and Dovey's Cistern. It is axis F. of the Map and Sections.

4. The axis G is that of Capewell and Dovey's South-dipping slope, and is seen in Quigley's Hollow N. of his old drifts.

5. The axis H is seen just S. of the Spring below the mouth of Quigley's Hollow, and crosses Silver Creek in Fitzimmons Spur.

The thick beds of conglomerate and coarse sandstone in the Red-Ash Coal-measures, useful for recognition of the coal-beds, are :—

1. A conglomerate lying between the N. and S. Diamond veins. It is cut in Neill's Tunnel, and must therefore be cut in the Casca William Red-Ash Tunnel.

2. Another overlying the S. Diamond, of which it forms the roof. It is a coarse pebbly sandstone, weathers pinkish and yellowish, and bleaches grey.

3. A conglomeritic sandstone of the synclinal axis S. of Neill's Breaker. This third bed forms next S. an anticlinal, and probably immediately beyond it another synclinal axis.

The road which passes from Silver Creek over to Lick Run, leaving the former a few yards S. of the Valley Furnace, crosses the anticlinal which lies immediately S. of the Furnace. The dips on the E. side are perpendicular and inverted, and on the S. side steep and then gentle. It leads out into the Lick Run Valley, and to the end of the lower dirt-heap of the Lick Run Works. The argillaceous mealy sandstone, with conglomerate which underlies the folded synclinal, seen next N. of the furnace, is seen on both sides of this anticlinal. The line of this last would cross Lick Run near the old Breaker.

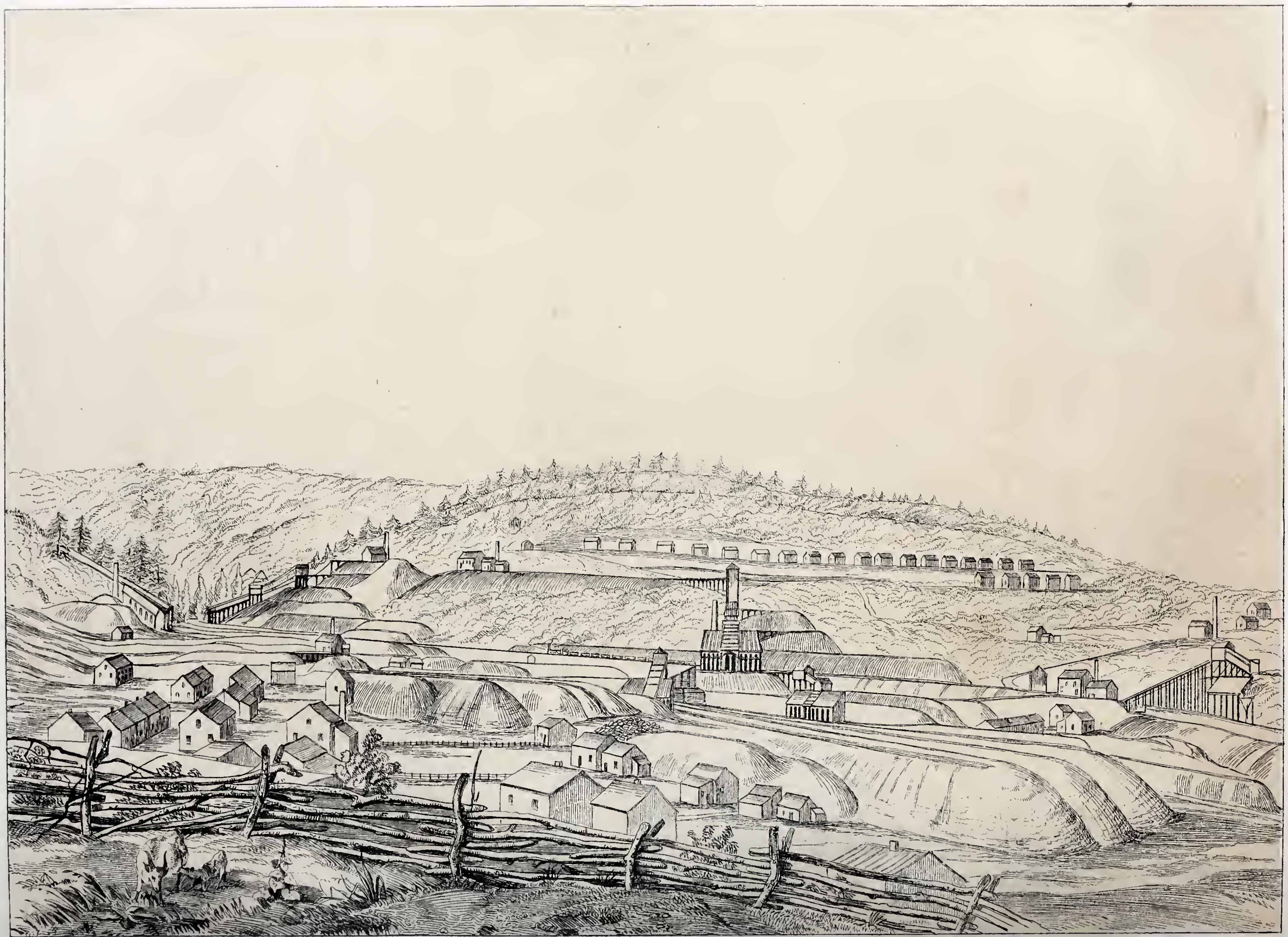
On revisiting this road, we found the strike of the mealy sandstone on the S. side of the axis to be N. 73° E.

This soft conglomeritic sandstone appears to be inferior to that which underlies the Peach Mountain Coal of Casca William, and even to the Clarkson Coal of that vicinity. In other words, we are here on the S. dips of the first anticlinal N. of Middleport, but a little lower in the series than anything there lifted to the water-level. This vein places the conglomerate supporting the Casca William Peach Mountain bed in the centre of the S. basin of Lick Run, but high on the knob E. of that valley.

COALS ON SILVER CREEK.

The lowest coal fully known on Silver Creek, in 1853, and displayed in a gangway driven E. about 300 yards, has an average thickness of 9 feet. It is so represented in the Silver Creek Section, where its position is also shown. It consists of two benches, the upper varying from 4 to 5 feet in thickness, and the lower one from 2½ to 3 feet, with a slaty parting between them. It is a good Grey-Ash coal, perfectly pure, the dip not too steep for mining.

The Big Coal—formerly Chadwick's, and now mined by Guiterman, Harper, and Company—is from 50 to 60 feet thick, the dividing-slate in some places being 10 feet thick, in others only half a foot. The more correct average thickness of this Big Coal is 45 feet, divided into benches, with partings of slate and soft mining. It is said to yield two-thirds merchantable coal. At the outcrop its dip is 40° S. Length of breast to outcrop 190 yards : the outcrop is on a well-marked bench of the mountain. The gangway was driven 900 yards E. The top keeps regular, while the bottom flattens in places when the coal becomes thicker. The capacity of this coal-mine is such, that the miners might easily load 60 cars per day, of 5 tons each.



Dalson

SILVER CREEK COLLIERIES IN 1853.

Tucker's Big Coal.—The outcrop of this coal is about 45 yards above the water-level, making it 150 yards to the bottom of the slope at the time of observation: the thickness of the coal varies from 3 to 13 feet. In the slope the dip is steeply S.

Neill's Slope is on the *N. Diamond* of Casca William, or that next N. of the Casca William Slope. A tunnel under water-level goes from the N. Diamond to the S. Diamond and Neill mines, both coals to the E. and W. of the centre of Silver Creek Valley. This colliery estate runs 1¼ miles E. and W. The tunnel is 58 yards in length; that at Casca William is 55 yards. Both cut the same measures. Neill's cuts a conglomeritic sandstone 20 yards S. of the North Diamond Coal, and it averages almost 15 feet in thickness. Dip in the tunnel 42°, in the slope 38°.

Big, or North Diamond.—Seven feet of dirt. It is faulty, and contains no merchantable coal. It is identical with the Gin Vein in the new slope of Chadwick and Co., on S. dip of axis G. The South Diamond has 6 feet of a deep Red-Ash coal, perfectly pure, with not an inch of parting-slate. There are two other higher coals S. of the South Diamond, between it and the hard sandstone and conglomerate of the synclinal axis. Close above the South Diamond is a sandstone and pebbly rock of considerable thickness.

The Primrose Coal on Silver Creek has not been wrought; and now that the new railroad is placed so high, it will not be mined above water-level.

The coal on Lick Run, wrought by Murray, is the same as that worked at Silver Creek in the slope N. of the furnace. The coal seen in the anticlinal flexure directly S. of the furnace is evidently a seam *under* the folded one, or Peach Mountain Vein, of the synclinal of the furnace.

Capewell, Dovey, and Southall's Peach Mountain Slope, near the Valley Furnace, on the W. side of Silver Creek Valley, was not wrought in 1853.

The Peach Mountain Coal is said to be in strike with the seam which outcrops just below the furnace. The slope is 50 yards below the water-level. The pitch of the coal is steady at 45° S. A gangway was driven W. towards Eagle Hill (Zachariah's Run) 700 yards. There were 550 yards of good coal; other 150 yards were faulty. The coal has an average thickness of from 4 to 5 feet. There are three benches with undermining between them; the lower bench is 18 inches thick, of the best quality of coal; the top is of slate, poor and irregular; the bottom has a strong sandy slate,—thicknesses not proved. On going down, the slope encounters the *Perpendicular Vein,* causing confusion where it strikes it; beyond this it is regular. The slope continues about 10 or 15 yards. It is thought that the same coal is worked by Greene on Eagle Hill. The coal here called the Perpendicular Vein has a S. dip. In the Western Gangway they have tunneled across, and struck the Perpendicular Coal, and in a few feet the Slope Coal. The Perpendicular Coal varies in thickness, having from 2 to 5 feet of good sound coal; it is then nipped out Eastward, and the Slope Coal and Perpendicular Coal come together.

Twenty-five yards N. of the Peach Mountain is the *Little Tracey* Coal, from 3 to 4 feet thick; then comes the *Big Tracey,* which is 8 feet thick, N. of which is the Fitzimmon's Drift, leading about 150 yards to the W.

The bearing of Spohn Coal air-shaft from the opening on the E. side of the road is from 12° to 14° S. of W.; dip of coal about 45° S. A drift was recently opened below the furnace 500 feet, showing measures and coal dipping from 20° to 30° S., but faulty.

ANTICLINAL AXES TRACED.

Axis D.—This anticlinal was traced from the point of the spur at the Casca William White-Ash Slope, along the flexure of Guiterman's Big Coal at Silver Creek; thence through the high valley S. of Mine Hill, N. of Ravensdale and Crow Hollow Hill, and N. of Milne's and Snyder's Upper and Lower Slope collieries, and in the arch of the conglomerate, which there supports the Skidmore Coal, and out to Mill Creek Valley at Johns' great dirt-heap.

Axis E.—This was traced from Casca William, at the flexure of the South Diamond Coal, through to Silver Creek, immediately N. of the slope on the Big Diamond (Neill's), and across Silver Creek, where it passes directly under the Public School-house, and thence over the watershed and down a ravine leading into the valley of Zachariah's Run at Windy Harbour. Declining Westward, it is the flexure which causes a great and sudden change in the trend of the Mammoth and overlying coal at the head of Crow Hollow. This axis appears on Mill Creek, passing under the swell of hills S. of Milne's and Snyder's Slopes, whence it crosses the valley to undulate the Big Vein and the Primrose Coal on the opposite side W. of St Clair.

Axis F.—This is the axis next S. of the Red-Ash Slope at Casca William, from whence we traced it through Lick Run directly N. of the massive bed of conglomerate, where it is exposed on the old railroad, above the most Northern drifts; thence it was followed patiently to Silver Creek, through Quigley's Hollow and the hill W. of it. It appears on Silver Creek as the anticlinal in the centre of the double fold of conglomerate cut by Tucker's Railroad. Across Silver Creek it appears in the low spur next S. of that which sustains the School-house, and, rising and expanding Westward, it comes out on Zachariah's Run just N. of the folded synclinal vein of Windy Harbour. This is probably the same anticlinal which passes through Crow Hollow on its S. side, or on the N. side of the spur which separates this from Ravensdale. At Mill Creek it seems to be discernible in an anticlinal indicated a little N. of the line of Carey's Shaft, where it lifts the Primrose to its shallow position in the shaft, and throws out the Orchard Coal altogether from the ground N. of the hill.

Axis G.—This anticlinal passes Silver Creek immediately N. of the great bend of the new Switch-back Railroad, and on the W. side just N. of the Slope Colliery, on the Diamond or Gin Coal. It crosses Zachariah's Run through the steep ravine which separates the two synclinals of coal, and is seen in the N. end of the Ravensdale Tunnel as an inverted flexure, folding the Primrose back under itself. This inverted flexure crosses Crow Hollow, and then Mill Creek a little S. of what are called the Hancock Coals, which are folded by it into a close oblique synclinal.

Axis H.—This has been traced from near the mouth of Bushy Valley on Casca William, through the hill N. of the old furnace on Silver Creek, thence through the crest of this high ledge to Zachariah's Run, where its arch-like character is well exposed in the cutting on the drift-road S. of the Gin and Perpendicular Coals, where the axis itself is seen in an arch of conglomeritic sandstone. It appears in Ravensdale in a bold hill S. of the mine, wrought in the folded synclinal of that vicinity. Keeping the same belt of hills, it ranges across Crow Hollow under similar features, and through the watershed which separates that valley from Mill Creek. Holding its course through the Southern summit of the broad double-topped hill, it causes the steep N. dips of the so-called Perpendicular Coal of both Ravensdale and Mill Creek.

To the S. of this axis, throughout its whole length, is the well-maintained *Basin* of the *Tracey and Peach Mountain Coals.*

COAL-SEAMS ABOVE WATER-LEVEL IN THE SEVERAL BASINS BETWEEN SILVER CREEK AND MILL CREEK.

It will be useful to the reader, before presenting him with details of the collieries and local workings between Silver Creek and Mill Creek, to set before him a general sketch of the uppermost or accessible coals contained in the slender synclinal belts called basins embraced within this tract. In tracing in a previous chapter the anticlinal axes which traverse it, mention was made in each instance of the lowest coal-beds elevated by them ; my present object is to show the highest seams resting above the synclinal bends, so that between the two we may be made aware of the whole immediately accessible contents of each basin. Beginning with the N. strip, and proceeding regularly Southward from basin to basin, we identify the coals outcropping within them as follows :—

Basin D E.—On Silver Creek, so feeble are the flexures D and E compared with axis C of Mine Hill, that neither of them produces more than a trivial roll of the superficial coals on the wide South-dipping slope of that broad anticlinal wave ; and, as a consequence, all the coals of basin *D E* are seen dipping to the S. at angles of 45° or 50°, except those immediately involved in the narrow saddle E ; namely the Little and North Diamond beds, which, for a very short distance, dip steeply N. Thus, then, the basin, or more properly the belt, *D E*, embraces all the lower White-Ash coals from the second below the Guiterman, all the upper White-Ash or Big Coal group, the Grey-Ash or Primrose Coals, and the two lower Diamond beds, in all thirteen, of which at least ten are workable.

On Zachariah's Run the chief coals opened in this belt are the Skidmore and the Big or Mammoth Coal, and the other White-Ash seams of the upper White-Ash group. The N. side of the basin—namely, the S. slope of South Mine Hill—contains the outcrops of the upper members of the lower White-Ash group, or Chadwick's and Guiterman's thick seams, but the S. side would seem not to embrace the Primrose or Orchard Grey-Ash beds. It would appear, in other words, that the synclinal line of the basin, or the keel of this one-sided boat, rises slowly Westward. This is further confirmed by the fact of our finding the Big or Mammoth Coal at the head of Crow Hollow, just under the surface, directly on the anticlinal axis E. Advancing to Mill Creek the belt is almost entirely a South-dipping one, but the inclinations are much more gentle than at Silver Creek and Zachariah's Run. It contains on Mill Creek about the same coals in its S. half as it does at Zachariah's Run, that is to say, the upper White-Ash group, with the addition of the Primrose ; but, embracing a very feeble N. dip, it scarcely deserves the name of a basin at all.

Basin E F.—The narrowness and gentleness of the flexure F causes the basin N. of it to contain, like the belt *D E*, a very trivial amount of N. dips ; indeed, it exhibits at the water-level no North-dipping coal. At Silver Creek it includes under a S. dip all the Diamond group, namely, the Little and North Diamond coals at Neill's Slope, and the South Diamond, and a 3-feet thick seam above this, besides a very thin band of coal still higher up. Probably at a deep level the undulation F is still more flat, and in this case the belt *E F* is but the N. side of the broader basin *E G*, which is the especial basin of the Diamond group. On Mill Creek it is a very flat wave, not a defined basin at all, containing the Primrose Coal nearly at the water-level.

Basin F G.—This belt on Silver Creek has a very narrow South-dipping side—indeed, it shows no South-dipping coal-bed, but its S. half includes the South Diamond Seam, and the coal next above it, under a very steep N. dip thrown off from axis G. These coals have been wrought in it on Zachariah's Run, and the whole Diamond group has been mined in this basin in Ravensdale, where a tunnel cuts the synclinal axis. At Mill Creek all the coals of the belt dip S., for the axis G is there an inverted one, and folds the Hancock bed into a compressed South-dipping **V**. It is the basin of Cary's Shaft.

Basin G H.—The belt *G H* at Silver Creek is, from the relative feebleness of the anticlinal H compared with G, the reverse in structure of the basin *F G*; that is to say, its N. dips are very narrow, while its S. ones, including the Diamond Group, occupy nearly the entire belt. These Diamond Coals have been mined at Zachariah's Run, where one of them, the North Diamond, goes under the name of the Gin Coal. The axis H becoming rather more prominent by the time it reaches Mill Creek; some of the South-dipping Diamond Group are there reversed by it at water-level into a very steep N. dip, the so-called Perpendicular Vein being one of them, probably the South Diamond.

The Peach Mountain Basin, embraced between the anticlinals H and I, contains on Silver Creek, as our Section shows, the Peach Mountain bed, Big and Little Tracey, and other coals of the Peach Mountain group, with moderate S. dips on the N. side from axis H, but steeply inverted ones between axis I and the synclinal fold; indeed the synclinal flexure is here dislocated, and the overturned, or S. half of the basin, has its softer strata in a very crushed condition. The same condition of things prevails on Zachariah's Run, where the **V** formed by the two outcrops of the Peach Mountain bed is nearly as narrow and obliquely South-dipping as on Silver Creek. (See Section.)

At the valley of Mill Creek, the synclinal axis having risen, and the flexure having expanded from the flattening-out of the previously compressed and inverted anticlinal I, the S. side of the basin exhibits only a moderately steep N. dip, while the N. side shows a broad belt of strata dipping at about 35° S. As already mentioned, the Peach Mountain Seam is, throughout all this extent of the basin, the uppermost of its coal-beds.

Basin I K, or complex Belt of Middleport and Norwegian, between Silver Creek and Mill Creek.—Overlooking for the present the imperfectly known subordinate flexures I and J and K K K K of the division of the belt between New Philadelphia and Mill Creek, I shall regard this tract as one wide and deep synclinal trough undulated on its sides, and having its synclinal axis in the conspicuous trough which extends from New Philadelphia through Cwmbola to the N. base of the Gate Ridge. It is impossible, in the present imperfect state of development of this obscure portion of the coal-field, to determine what coals occupy the very uppermost or central position within this deep basin. At Cwmbola and Belmont the Lewis Vein of those localities is the highest important seam; it basins almost immediately under the E. and W. reach of the Schuylkill. Going W., the basin widens by the gradual separation of the anticlinal J from the main compressed axis K, and the steep N. or perpendicular dips of the S. side, near Belmont, subside to 45° N., so that the small coals of the Sandrock series overlying the Lewis Coal, occupy a broad belt at the synclinal axis, twice as wide at least as the steeper trough they form at the river between Belmont and Cwmbola.

DETAILS OF THE SEVERAL COLLIERIES BETWEEN SILVER CREEK AND MILL CREEK.

Novelty Colliery ; Slope W. of New Philadelphia, mined by Connor and Roads).—The Spohn Coal dips from 30° to 35° S., is 4½ feet thick, with 9 feet of slate on the top, and a fine hard sand-rock below. Immediately on the top of 9 feet of the slate there is a 3-feet-thick coal, with a hard sandstone top. A thin leader occurs 20 yards N. of the Lewis Vein ; then comes what is locally called the Sandrock Vein.

About 20 yards N. of the Spohn Vein is a leader or thin coal from 12 to 18 inches thick, and 80 yards further N. is the Palmer Coal. The Palmer Coal occurs at Cwmbola, but *not* at Five Points. On the Spohn Coal there are drifts all the way to Five Points. The slope at Connor's and Roads' is in all probability in the *Spohn* Coal, and not, as some suppose, in the Sandrock. There is a slope on the Palmer Coal which has 3 feet of good coal all in one bench, and dips from 35° to 36° S. Below the coal lie 18 inches of loose dirty slate, then a yellowish-grey very argillaceous sandstone, about 6 feet thick, and regular. The top rock is a firm and smooth black slate, and has stood in the gangways without pillars for 300 or 400 yards.

The drifts on the Palmer Coal were 800 yards E. and 700 W.

The *Charles Pott* Coal is 38 yards N. of the Palmer Vein. It dips 38° S., and averages 2½ feet of good coal, but it is in many places poor. Its drifts were 400 and 500 yards E. and W.

The *Clarkson* Coal is about 100 yards N. of the Charles Pott bed ; the dips vary from 28° to 45°. Its average thickness is 5 feet ; it is much broken and dirty ; the drifts were 500 yards E. and 100 yards W. The Peach Mountain Coal of Valley Furnace lies 500 yards N. of the Spohn Vein.

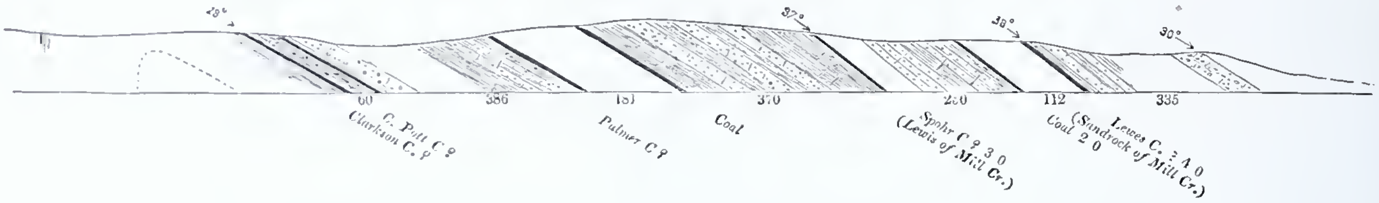
The *Slope* is down 140 yards : the coal averages 4½ feet ; it is good on the W. side for 800 yards, which is at the end of the gangway. On the E. side it is good for 400 or 500 yards, when a stone fault, running N.E., cuts off all the coal. The coal lies in two benches ; the bottom bench is about 2 feet thick, and is rather the best. The upper bench is 2½ feet thick. The benches are irregular, and sometimes the coal is all in one solid block. The Spohn Coal is very subject to jumps or sudden sharp small folds in the gangways. The coal will turn up for 10 feet perpendicularly, and then go down with the regular pitch.

CWMBOLA, HUBLEYVILLE.

Cwmbola Colliery, mined by W. Y. Agard and Company.— This slope is on the *Lewis* (the true *Sandrock* of Mill Creek) : the dip at the top is 38°, and at the bottom 23½° ; the coal contains 4 feet of coal in three benches. On the E. gangway are two benches of slate between the coals, but on the W. gangway there is but one. The W. gangway was driven 450 yards, and the E. 350 yards, but it is somewhat confused. The roof is of good Bony coal, the bottom is the same : the slope length is 225 yards ; it has four lifts and three gangways. From the bottom of the slope, about 55 yards towards the W., commences the tunnel, which is driven N. about 65 yards. At 37 yards it cuts a 22-inch coal, with mixture of coal, slate, &c. ; this is called by some the Yard Coal. The tunnel passes through sandstones, &c. The E. gangway curves rapidly to the N.

The slope on the Spohn (or true Clarkson) Coal is 102 feet down from the surface. The coal above water-level is worked out by drifts.

FIG. 166.—Section at Cwmbola from anticlinal J, looking E.—1 *inch* = 400 *feet*.



The *Sandrock* Coal, in ranging Eastward from Cwmbola, passes into the flats of the river. The Lewis Coal is caught in the hill at the road.

Synclinal Axis of Cwmbola.—At the E. end of the village is a good exposure of a synclinal axis along the bank of the river. On the S. side of the basin is a powdery exposed rock in the river. The dip is vertical, then N. nearly vertical; from this, going up the stream, it becomes from 60° to 70°. The strike of the vertical dips is N. 68° E., cutting the spur from Bare Ridge E. of the town. From these N. dips to the middle of the basin is 125 feet. The synclinal axis is 325 feet S. of the upper pier of the railroad bridge, opposite the engine-house.

Havener's (formerly), now Colahan's.—The shaft at Havener's, at 38 yards down, strikes upon a seam (the Blacksmith Coal) which rolls into a kind of saddle or egg-shaped turn. From this a cross-cut N. reaches the North Gate Coal. There are three nearly vertical coals S. of his shaft before we meet the regular South-dipping coals—the Black Mine and Tunnel Coal, &c. Colahan, making the above statement, adds that the Gate Coal cut in the tunnel, 22 yards N. of the foot of the shaft, which is thin, with a perpendicular N. dip, turns, in crossing the ravine, to a steep S. dip, and at the end of the gangway, 280 yards farther, it is regular and good, dipping a little S.

PINKERTON'S TUNNELS, BARE RIDGE (ABANDONED IN 1853).

Eastern or Upper Tunnel.—Length 115 yards. The coals all basin above the tunnel-level. The tunnel was driven 40 or 50 yards S. of where the veins ought to be, but for a synclinal axis. The S. dips were 35° at the entrance; the basin was about 70 yards in. The N. dips of the basin were 35°; they cut one little seam in the roof of the tunnel, 18 inches in thickness. The rocks were slaty sandstone.

Western or Lower Tunnel.—The dips are nearly vertical. At the mouth they are S., and then N. It was driven in 117 yards to North Gate and Havener's Big Coal: 15 yards in it struck a 4-feet coal; 4 or 5 feet of slate at the top and bottom. The North Gate Coal, at the end of 70 yards, is 4 feet thick, with good coal; 9 feet of slate.

Havener's Big Coal has from 5 to 7 feet of coal. Face of tunnel 60 or 70 yards. The rock is a hard coarse sandstone.

Christopher Rooney gives the following account of the Lower Tunnel: For about 15 yards the rock was soft and sandy, then a small leader 18 inches thick, 30 yards of fair ground, 30 yards of hard sandstone, 90 yards to the first $3\frac{1}{2}$ or 4 feet of coal; 8 yards farther another 4-feet-thick coal; 10 yards more, a small coal of 18 inches or 2 feet. The dips are vertical throughout.

The line of strike from the mouth of the Lower Tunnel in an Easterly direction ranges over the flat S. of Cwmbola, and strikes a little N. of the crest of the spur which points out Northward from Bare Ridge, on the other side of which is Havener's. The hill opposite Cwmbola is cut out by denudation into a concave sweep.

Between Cwmbola and Havener's Breaker in the railroad cut, at the foot of the spur from Bare Ridge above spoken of, we find shales and slates; rocks evidently on the N. side of the synclinal of Cwmbola.

OLIVER'S COLLIERY, S. SIDE OF BARE RIDGE, (OWNED BY SHIPPEN AND WHITAKER).

The *Rabbit Hole* Coal is the first coal opened and worked. Across the strike from it to the tunnel coal is 170 feet. It is drifted on, and is 3½ feet thick.

The *Faust* Coal is known to exist here, but has not been worked.

The *Tunnel* Coal is the only one which has hitherto been much worked; it has been wrought at intervals for fifteen years, and has been driven as much as a mile to the Eastward; dip from 30° to 35° S. It was worked W. of the Breaker; its thickness was 5 feet; the bottom bench had from 2 to 3 feet of excellent coal, there was a thin slate parting and 2 feet of coal in the top bench; then from 6 to 8 inches of slate and Bony coal for the roof; the slope is sunk 167 yards; the breast above water-level was from 75 to 100 yards.

Black Mine Coal is distant from the Tunnel on the outcrop 68 yards. It is cut in a tunnel driven N. from the bottom of the Tunnel Coal Slope at a distance of 71⅔ yards. It is now worked, and is but 3 feet thick, its usual dimension being 6 feet. From this tunnel, on a lower level, the outcrop of the Black Mine Coal is 175 yards.

The *Little and Big Lawton* Coals, N. of Black Mine bed, are drifted on, but are not now mined, and were found, as far as proved, to be irregular.

The air-holes on the Tunnel coal are traceable from this point Eastward to half-way down the hill, descending to the gap at Preston's, opposite New Philadelphia.

From Upper Bare Ridge, 100 yards from Silliman and Reed's Breaker, a tunnel runs S. into Sharp Mountain 300 yards. It cuts the Parker Coal.

A tunnel was driven Northward in Bare Ridge, in the vicinity of Oliver's, known as the Andrew B. White Tunnel; it is now closed up.

The following Section exhibits the effects of an anticlinal flexure, cut by this tunnel, in alternately pinching and enlarging the coal-seams, all of which are in an unfit condition for mining:—

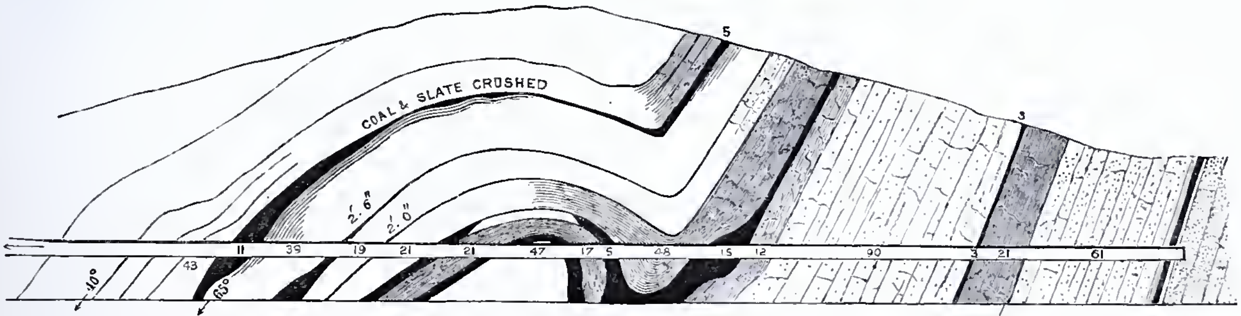


Fig. 167.—Section of Tunnel in Bare Ridge (Pott and White's).—100 *feet* = 1 *inch.*

ZACHARIAH'S RUN.

On the road between Silver Creek and Zachariah's Run, about one-fifth of a mile along the strike from the Valley Furnace, are two old tunnels, driven S. very close together. They crossed the outcrop of the coal in the sandstone which lies beneath, then passed into more Northern measures in descending the hill to the Eagle Hill Colliery.

Above Eagle Hill Colliery on Zachariah's Run :—

1. The *Dodson* Coal outcrops near the Shanty, about 500 feet above or N. of the uppermost coal synclinal.

2. The coal of the synclinal axis has a S. dip of about 40°, and a N. dip nearly perpendicular, being from 75° to 80°. The coal ranges from 6 to 10 feet in thickness, being 8 feet when perpendicular. On the W. side of the valley the two limbs of the coal are together, and make a mass of 20 or 25 feet of coal.

3. The *Little Perpendicular* bed is separated from the above coal by a conglomerate. It is a 2½-feet coal, dipping from 80° to 85° N., and is opened on both sides of the valley.

4. The next coal is of a steep S. dip (80°), and is called the Diamond; it is about 5 feet thick, but 200 yards up the hill it was 13 feet thick, though soft and worthless. It is distant from the Little Perpendicular about 150 feet.

5. Two coals are known between this and the Gin Vein. The N. one is opened on the W. side, and is found to be 7 feet thick, and inclining nearly perpendicularly to the S. It is about 300 feet distant from No. 4.

6. The *Bosbeshell* Coal is the North-dipping coal which follows next. It is regular, but soft, and very close in the hill to the South-pitching Gin Coal. The drift in the Gin Coal divides, so as to give access to both sides of the synclinal: the N. dips are about 70°, and the S. dips 40°. The North-dipping coal is good below, but grows bad followed upwards. The S. dip is very good downward. It is nearly all worked out. The Gin Coal of Chadwick, Dovey, and Southall, Silver Creek, is not the Gin Coal of Zachariah's Run, which, by our construction and tracing, belongs to—

7. A North-dipping leader, about 1 foot thick.

8. A good coal, about 4½ feet thick, having a N. dip of 80°. This is the North Diamond Coal, proved by tracing of the axes and the harder rocks. There is hard conglomerate beneath.

9. The Perry or Brook's Coal is 150 feet S. of No. 8; dip nearly perpendicular. This is on the N. side of the anticlinal of sandstone (Axis No. 5), and has been worked to meet the same on the S. flank of the same arch in a S. dip.

10. The Henderson Coal corresponds to No. 8 above; dip S. from 30° to 35°, about 4 or 4½ feet of coal; the bottom is rough, the top is good coal. It is also called Green Park.

11. *Fitzimmon's Coal.*—Dip 40° S.; it has from 8 to 9 feet of coal in two benches—1st, about 2 feet of good coal, then 2 inches slate; 2d bench from 6 to 7 feet of coal. The vein is said to be the best in this valley. It has been driven E. 600 yards. The *iron ore* about 15 yards below the Fitzimmon's Coal has been driven into for exploration.

Some 80 yards (? feet) from the mouth of the drift, thin dirty coal was found, which met the Fitzimmon's. Near the meeting there was a thickness of dirt and coal of some 30 feet; the small leader dipping S. only 20°. This is probably the small leader (No. 7) brought into contact with No. 11 by a fault. The form of the ground is peculiar.

Above the Fitzimmon's are about 50 feet of olive slate and shale, then Pea and Shot conglomerate and sandstone, all dipping about 30° S.

12. A small South-dipping coal, of 2 feet thickness; was not wrought.

13. *Rough* Coal, 7 feet thick; S. dip 35°.

14. *Peach Mountain,* so called, underlying slate and rock from 4 to 5 feet.

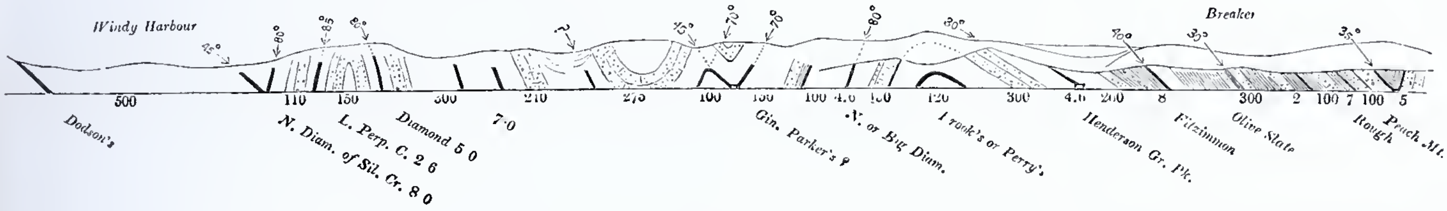
It seems probable, from careful tracing, that the synclinal bed of the Peach Mountain Coal of Zachariah's Run is the synclinal of the real Peach Mountain of East Norwegian. In this case the conglomerate which crosses Zachariah's Run at the Breaker is that which underlies the Big Tracey on Mill Creek. By both topographical and geological features the continuity of the Peach Mountain basin of Norwegian with that of Zachariah's Run seems to be fully proved.

Remarks upon the Zachariah's Run Section.—1st. The veins S. in descending order to the Breaker belong to the Tracey group; 2d. Thence down to the conglomerate of axis H to the Fitzimmon group; 3d. Thence below to the Diamond group. Thus the Gin Coal of Zachariah's Run is of the Fitzimmon group; the Perry is of the Diamond group, and probably the third from the lowest of that group.

Eagle Hill Colliery, Zachariah's Run—(Benjamin Titus, lessee; estate of Hewes and Baber).—Here the S. dips of the Peach Mountain are very regular, being about 35° S. There is also a perpendicular coal; the distance between the two outcrops is 11 yards. The owners have shafted on both beds, and determined the dips with accuracy: the coal, therefore, continues into this valley. S. of these are three or four beds, the Big and Little Tracey, &c. All the coal now taken (1853) is from the Gin Coal, about 500 yards N. of the Breaker.

The following cut represents the coal strata as they are developed on Zachariah's Run, with the local names of the coal-beds. It embraces nearly all the Red-Ash measures.

Fig. 168.—Section on Zachariah's Run, looking E.—1 *inch* = 400 *feet.*



BELMONT (FIVE POINTS).

Lewis and Spohn Coal of Belmont.—For the purpose of ascertaining the identity of the coal between Mill Creek and Belmont, the following examination and measurement were made:—

It was noted that the Sandrock Coal of Mill Creek had overlying it a massive Pea and Nut-conglomerate. This conglomerate was found on the bank of the river a little E. of Belmont, dipping 30° S. Measuring from the face of this conglomerate at water-level to the outcrop of the Lewis (so called), it was found to be a distance of 430 feet, which, when reduced to the horizontal, is about 335 feet—the true distance from the conglomerate face to the so-called Lewis Coal. This distance agrees so well with the distance between the same conglomerate and the *Sandrock* Coal on Mill Creek, as to lead us to conclude that the Lewis of Belmont is the *Sandrock* of Mill Creek.

After thus ascertaining their identity, it was found, by tracing the measures on the road from Belmont to Cwmbola, and also by the plotted map of the gangways of the respective workings, that the so-called Lewis of *Cwmbola* is also the Sandrock Coal. Both lie at the same distance N. of the conglomerate. Traced further E., the true Sandrock ranges into the swamp opposite Connor and Roads at New Philadelphia. The *true* Lewis, or so-called Spohn, crops out on the road from beneath its sandstone, and the true Spohn is worked by Connor and Roads.

Belmont Slope.—This slope is down on the local Lewis (true Sandrock) Coal. The length of slope in 1853 was 240 yards. Coal equal to 5½ feet in two benches—the lower 1 foot, and the upper from 4 to 4½ feet. The coal is good, and dips 35° S. Gangways run W. 600 yards. For the last 100 yards the gangway curves about 10° W., the bed having a dip of 30°. A gangway runs E. 540 yards. There are three lifts in the slope. The coal has 2 feet of hard slate above it, and 3 feet of slate below; also a band of crushed coal or dirt, and a leader of 3 or 4 inches.

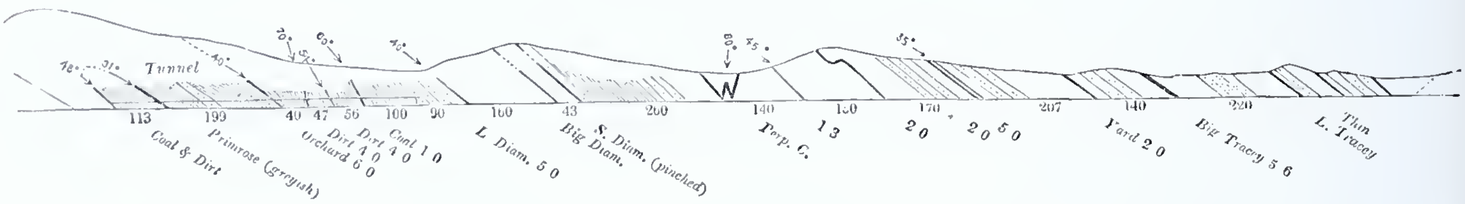
S. of the Sandrock Slope, about 70 or 80 yards, is a coal from 4 to 5 feet thick.

From 20 to 25 yards under the Sandrock is a 2-feet coal, locally called the Yard.

About 90 or 95 yards under the Sandrock is the Lewis (local Spohn) Coal. It has a slope sunk upon it down 140 yards, 120 yards below the water-level. It has two lifts.

From 6 to 9 feet from the top of this coal there is a 2½-feet coal, beneath which are 2 feet of slate, 4 feet of fireclay, and 2 feet of slate again. The Lewis is about 3½ feet thick in two benches; the lower is from 1 to 1½ feet; the upper about 2 feet—dip 37° S. The gangway was driven W. about 600 yards. 40 yards from the end, the vein turns towards the W. as the Sandrock does. These 40 yards are confused and faulty.

Fig. 169.—Ravensdale Tunnel.



Ravensdale Tunnel.—The farthest coal cut in the tunnel dips S. 45°; it meets the Primrose Coal dipping S. 35°, and forms an inverted axis; the two coals are about 50 yards apart in the tunnel. The back or N. coal is 10 feet thick, and the Primrose is 7 feet thick. The Back Coal is locally called the Tunnel Coal. The crown of the arch would be about 50 feet above the tunnel-level. Between the two limbs of the anticlinal we find sandstone in part. The Back Coal has a breast of 63 yards; it contains much dirt. The crest of the anticlinal dips towards the E. until it reaches the gangway-level.

A leader was struck about 12 yards N. of the Primrose from the E.; the gangway runs 400 yards from the main tunnel. It is 3 feet thick, and is probably folded like the Primrose bed. It lies *under* the sandstone. They both crop out on the surface about 30 yards W. of the tunnel, separated on the surface by only a few feet of slate.

The bottom bench of the *Primrose* Coal contains 18 inches or 2 feet of Bony coal; the top bench is good coal, from 4 to 5 feet thick; the roof is a soft slate, and a thin sandstone without pebbles.

About 66 yards S. of the Primrose Coal, in the tunnel, is the Orchard Coal, dipping about 40° S. It is 4 feet thick, and is a true *Red-Ash* coal. The Orchard Vein was worked out to the E., and found very faulty. To the W. it has been worked into Crow Hollow until it ceased to be good coal. Between the Orchard and Primrose beds are soft slates. Over the Orchard we find 4 feet of slate and then hard sandstone, but no important seam of coal. There are two small seams, neither of which will measure 2 feet: there is a mere leader between them. It is 92 yards from the Orchard Coal to the tunnel's mouth. Outside of the tunnel, at a distance of 36 yards, is a small leader, and 40 yards S. of the tunnel is a coal dipping S. 40°, called the Diamond (see Ravensdale Section). The South Diamond has been found only on the W. side of the hollow dipping S. A coal, which shows itself on the W. side of the hollow, is not here known. There are here two *perpendicular* beds, each 5 feet thick, and separated by 10 feet of rock; they are much confused, and form a double fold like the letter W. The N. one of these, worked E., became thin, and was found 46 feet from the other. The S. perpendicular was worked E. for 400 yards. It was worked by a gangway at three levels. The hill, containing the perpendicular coal on its S. side, terminates in a ravine opposite the mouth of the tunnel.

S. of the perpendicular bed is a coal about 15 inches thick, dipping steeply S. It has been shafted on. 75 feet S. of this, on the outcrop, is another seam. This coal basins and saddles on the hill, and the outcrop at the water-level is at the foot of the Breaker. It is underlaid by a hard sandstone and a little pebbly rock: it has not been worked.

We have next a considerable thickness of sandstone and olive slate, dipping S. 30°, opposite to the Breaker. S. of this, and almost upon the sandstone, is a double seam. The N. or bottom bench is about 5 feet thick, and the upper is 3 feet thick, with 2 feet of slate interposed.

At the bend of the railroad in Ravensdale Hollow, near the houses, is a quarry of sandstone dipping S. 35°. It has all the features of the sandstone which lies under the Peach Mountain Coal. It is overlaid by olive slaty bands, and by the small pebbly rock seen in the turn of the road on Mill Creek in the synclinal of Peach Mountain at Old Tracey Drifts. This quarry shows some 30 feet thickness of rock, which is seen forming a crest on the W. side of Ravensdale. S. of this is a sloping shaft, showing a coal and overlying slates, with regular S. dips of 35°; and S. of it again an outcrop of sandstone, seemingly identical with that on the N. side. Between these two outcrops is the Peach Mountain basin, very narrow.

Immediately N. of the axis of the tunnel there is a South-dipping coal, the return of the Primrose N. dip.

CROW HOLLOW.

In descending the hill to Crow Hollow, near its head, there is a coal cropped on by Silliman: it is probably the Black Valley bed. On the E. and W. trend of the road in the S. side of the Crow Hollow ravine is the outcrop of the Black Heath Coal. The Big Coal is not many feet under the bed of the valley at the tunnel, and rises with a very gentle ascent; then, towards the S. again, we see at the roadside descending Crow Hollow, the Primrose hard rock; over it the first S. dip, then the N. dip, and then the second S. dip at the old air-hole.

South of this is the outcrop of the Orchard Coal crossing the valley. The Primrose is worked through from Ravensdale to Crow Hollow on the first S. dip, and on the N. dip, but not on the second S. dip. It is worked for a short distance towards Mill Creek on the W. side.

The Orchard Coal is worked W. from Ravensdale to Crow Hollow, but is not worked on the W. side of Crow Hollow at all.

The Hancock Coals are not worked either on Ravensdale or Crow Hollow.

The Lower Diamond bed is mined through from Ravensdale to Crow Hollow. On the E. side of Ravensdale it is worked for a short distance.

The Big Diamond bed is not opened on Ravensdale or Crow Hollow.

The Upper or South Diamond Coal is drifted from Crow Hollow eastward a short distance: it is not worked on the W. side, nor opened at Ravensdale. The rock over the Diamond group is visible in Crow Hollow.

The Perpendicular Coals are seen in Crow Hollow. Here the synclinal belt is a confused basin, with very much the features it has on Ravensdale; but the coal was better on the N. dip through to Ravensdale than anywhere else. It was confused Westward for 500 yards; indeed, there was no good coal, except, perhaps, 1000 tons.

A boring by the North American Company, sunk to 385 feet, struck a coal-bed said to be 7 feet thick; and several smaller seams were struck before reaching this 7-feet bed, one of them 4 feet thick.

MILL CREEK (ABOVE ST CLAIR).

Structure East of Johns' Colliery.—The outcrop of Johns' Seam on the N. lies along the flank of Mine Hill, and is traceable for a great distance E. The shaft opened by Samuel Silliman south of this line marks, we think, the continuation of the anticlinal disturbance seen in the small arch or wrinkle of sandstone near the slope on Mill Creek. This may be conceived, in its extension Eastward, to become a sharp anticlinal fracture, with perhaps some inversion at the surface, bringing the conglomerate and subjacent sandstone, which all lie above the Johns' Seam, into nearly vertical dips, and making the coal near the surface to take a like position. The main broad anticlinal to the S., in expanding Eastward, and being stripped on its summit and on part of its S. slope, not only of the great overlying coal, but also of the conglomerate which lies beneath it, brings to light a small coal which has here been shafted into on the N. side of the flat anticlinal near its crown.

A shaft sunk by Samuel Silliman struck coal dipping perpendicularly, and by tunneling N. and S. it has been proved to be 70 feet thick. The Nut-conglomerate is seen about 35 feet S. of the shaft, dipping steeply to the S. Some persons regard this as the N. side of the anticlinal, and the coal, the N. or perpendicular dip of Milnes and Snyder's Seam.

Johns' New Slope.—The coal here dips 38°. In 1853 the slope was down 60 yards. Thus far the coal was very regular: it had three benches; the upper one contained 3 feet of coal, the middle 7 feet, declining rapidly Eastward, and one-fourth of a mile off was only 2 feet thick, the rest being dirt. The lower bench was from 17 to 30 feet thick.

ST CLAIR, MILL CREEK.

Pinkerton's Tunnel is 700 yards W. of the Breaker, and runs from the Seventeen-feet Coal, so called, to the Mammoth. Over the Seventeen-feet Coal are 30 feet of soft slate, then thin coal, then coarse conglomerate rock 180 feet.

The Mammoth Coal is from 18 to 24 feet thick; the dip from 28° to 30°. At the tunnel, the slate between the Mammoth and 7-feet coal is 12 feet thick: the coal averages 7 feet thick; it runs from 5° to 10°. On the top of this is a sandy slate and argillaceous sandstone 12 feet thick, which runs to nothing one mile to the W., then coal 3 feet. S. from the 3-feet coal, we pass slate or shale with iron ore to the Black Valley Coal, which is 4 feet thick.

Milnes and Snyder's New Slope.—This, in 1853, was 278 yards long. It entered at 158 feet above the level of the railroad at St Clair. The dip of the Slope is S. 10° W.; it is slightly flat for 100 feet in the bottom of the Slope, then ascends 5° for 90 yards; then again, at the bottom of the Slope, a gangway is driven W. at right angles for 130 yards. Another gangway-level is going off from the bottom of the Slope, and is flat all the way. Driving Eastward, the coal rises in all directions, basining. The dip of the Slope in the lower level is 18° S.

McGINNIS'S NEW SLOPE N.E. OF ST CLAIR (CAREY'S PROPERTY).

The Slope was sunk 165 yards; a hole was driven 76 feet further, to prove the dip of the seam. The dip of the Slope was 17° S.; dip of the coal in the hole 35°. Had in 1853 one lift, gangways E. and W. from a point 140 yards from the top of the Slope, the E. gangway driven 125 yards, and W. 200 yards. The gangways are somewhat winding. From each gangway, tunnels are driven S. to the 7-feet coal. On the E. side the tunnel is 10 feet 3 inches long; on the W. only 7 feet. The Mammoth bed is from 18 to 25 feet thick, the overlying seam is from 7 to 9 feet thick. The basin was not then reached. The basin of Milnes and Snyder dips to W.; therefore, though this slope starts at a lower level, it had not gained the coal.

Carey's Shaft.—This coal-pit is situated a short distance S. of axis F of the basin *F G*. Its dimensions are 10½ feet by 18 feet. It intersects the Primrose Coal at 122 feet below the surface, and the Mammoth or Big White-Ash bed at 438 feet. From Carey's Shaft to Pinkerton's outcrop of the Mammoth Coal is 740 yards in a N. and S. line. The boring which preceded the shaft or pit, only recently completed, indicated three coal-beds, two of them very thin ones, between the Primrose seam and the 7-feet thick companion coal of the Mammoth bed. That next beneath the Primrose bed is the Flowery Field Coal of our Section: it is called on Mill Creek the Holmes Coal.

The annexed Table displays the depths at which the several coal-seams were reached, and approximately the nature of the strata between them. No boring can be deemed accurate in its indications of the thicknesses of the coal-seams, as Bony coal, and even very coaly shale, are sometimes mistaken for true working coal.

TABLE.

	Thickness.		Depth from Surface.	
	Feet.	Inches.	Feet.	Inches.
Rock and slate,	119	0	...	...
Primrose Coal,	3	0	122	0
Rock and slate,	68	0	...	...
Holmes Coal,	4	6	194	6
Rock 64 feet, slate 10 feet,	74	0	...	...
Coal,	1	0	296	6
Slate,	51	0	...	...
Coal,	1	8	322	2
Rock 54 feet, slate 18 feet,	72	0	...	...
Coal, 7-feet vein,	8	6	402	8
Slate,	14	0	...	...
Mammoth White-Ash,	22	0	438	8

BORING IN CROW HOLLOW IN BASIN *FG*, ON THE ESTATE OF THE NORTH AMERICAN COAL COMPANY.

An experimental boring was completed in 1853, under the direction of Mr P. W. Shaeffer, mining engineer, to test the depth of the Mammoth White-Ash Coal on the lands of the North American Co., in the belt I have called basin *F G*. It was judiciously located a little N. of the outcrop of the Primrose bed. A shaft sunk here will command a good field of the thick and valuable Mammoth seam, in the somewhat gently South-dipping side of the basin *F G*; but the rather abrupt axis G is likely to intercept the progress of mining Southward, after passing the synclinal axis, distant from the boring only a few hundred feet. The following Table exhibits the strata penetrated by the bore-hole. A comparison of it and the preceding table betrays some curious discrepancies in the thicknesses of the strata, especially the sandstones, ever the most inconstant members of our anthracite Coal-measures.

TABLE.

	Thickness.		Depth from Surface.	
	Feet.	Inches.	Feet	Inches.
Sandstone, slate, and rock,	88	1	...	...
Holmes Coal,	4	2	92	3
Sandstone and slate,	57	5½	149	8½
Dark-brown slate, with iron ore and a seam of coal,	35	0	184	8½
Slate, with leader of coal,	10	2	194	10½
Rock, and some slate,	189	1½	384	0
Slate,	21	0	405	0

to the Mammoth White-Ash Vein.

MILL CREEK, SOUTH OF CAREY'S SHAFT.

There is a 2-feet-thick coal N. of the *Orchard Seam* on Mill Creek. The latter bed should, from its angle of dip and the position of its outcrop, intersect the shaft, but it has been looked for in vain. The inference is, that it turns away towards the N. as it descends; it may, therefore, basin with the coal above mentioned. The Orchard is about 3 feet thick; there is nothing but fine fissile slate between it and the small coal, and the same exists between the two Hancocks. The two Hancock beds form a folded trough: they are distant at the outcrop on the hill about 50 feet; at the drift the distance is scarcely 10 feet, and a few feet below this they come together. There is a small anticlinal or roll between the Orchard and the Hancock Coals. The Hancocks are about 3 feet in thickness each, and were once worked about 150 yards E. of Mill Creek.

The *Big Diamond* Coal, 7 feet thick, worked at the slope, is found to flatten as it descends. About 200 feet below water-level it is flat, and then turns up. At the flat part it is more than double the ordinary thickness; but, ascending on the N. dip, it is crushed and worthless, being not more than 15 inches in thickness.

The *North Diamond* bed is here a mere leader, and worth nothing. The South Diamond Coal is reported to be from 4 to 5 feet thick, and is traceable as the Green Park from East Norwegian to Mill Creek. This coal, certainly identifiable as such, is struck on the saddle in McGinnis's Shaft and Boring on East Norwegian.

Between the Yard and the Peacock Coals on Mill Creek are *three veins.*

The *Primrose* Coal on the E. side of the workings has a bottom of 3 feet of Bony coal; it contains 6 feet of good coal.

The position of the N. outcrop of the Peach Mountain Coal is near the Summit Tavern, W. side of Mill Creek. Between the Big and Little Tracey Coals, the chief rock is a sandy olive slate, or flaggy sandstone, passing upwards into olive shaly slates, weathering very ochreous. *Above* the Little Tracey are similar olive slates, passing upwards into sandy slates and flaggy sandstone, grey, greenish, and rather soft, often coarse, and sometimes pebbly. Above this, and immediately under the Peach Mountain Coal, are ochreous olive shaly slates.

Peach Mountain Basin, E. Side of Mill Creek.—From the Big Tracey Coal across the measures to the Little Tracey bed is 140 feet. From the Little Tracey to the synclinal axis of the conglomerate the distance is 200 feet. There is no room here for the Peach Mountain Coal.

UPPER RED-ASH COALS OF MILL CREEK.

Beginning with the Main Gate Coal on the E. side of Mill Creek Valley, and advancing N., the first coal is the *North Gate*, distant 175 feet, and the rock between Gate and North Gate is a coarse grey sandstone, slightly conglomeritic (pebbles pea size), and then thick shales.

2. The 2d *North Gate* is N. of the 1st 95 feet, and between it and the 1st North Gate are only argillaceous sandstones and shales. A few feet above the 2d North Gate there is a coarse angular speckled pebbly sandstone, the pebbles few, and only in certain layers. It is perhaps from 10 to 12 feet thick.

3. About 62 feet N. of the 2d North Gate bed is the 3d *North Gate*, in fault, and about 10 feet above it is a sandstone.

The white conglomeritic sandstone at the turn of the road, 670 feet from the Gate bed, is probably the same as that of the hill at the Norwegian at Temple's Tavern. A little coal in fault at 710 feet from the Gate bed is probably the coal of the synclinal axis.

A hard grey speckled sandstone, 10 or 12 feet thick, succeeds, which may be detected in the synclinal axis, where it is deeper than at Temple's synclinal on Norwegian. The position of the Little Dirty Coal (Temple's) is to the N. of the turn in the road. Then come the conglomerate and other measures on a S. dip, from 35° to 40°, all corresponding with the N. dips.

The Little .3d North Gate, under the name of the Little Sandrock of East Norwegian, overlies at the proper distance of, say 12 feet, a rough conglomerate and sandstone.

The *Big Sandrock* Coal is seen on the roadside, and in the drift under the road. This is the 2d North Gate Coal. A drift on the W. side of the valley is on same coal.

The *Yard* Coal of East Norwegian, or 1st North Gate, is opened by an old drift. There is a small coal above the Lewis, which is the small coal N. of the main Gate. All the elements agree, and this view of the identity of the Lewis and Gate Seams was maintained by Mr John Madison, an estimable mine-viewer, several years ago.

The *Little Lewis*, or Little Spohn Coal of Belmont, crops out South of the Lewis about 25 or 30 feet.

The *Lewis* Coal colliery is that of Snyder and Milnes, and that on the opposite or W. side is the colliery of Mr Bainbridge. There is no true Spohn Coal here, but a small 18-inch coal N. of the engine-house ; then the *Palmer* Coal at the drift.

A massive sandstone, pebbly, somewhat grey and speckled, lies between the Lower Lewis and the Palmer ; it dips 30° and 35°. Then directly over the Palmer is coarse sandstone, then coal, with olive shales between it and conglomerate, dipping 45°.

The Palmer answers to the South Gate Coal. It here averages 3 feet in thickness, one solid block. The so-called *Spohn* Coal dips from 30° to 35°; it outcrops on the road opposite the S. end of the barn. It averages 6 feet of coal.

Above the house are two coals at an old drift; the first S. is the *Robert Waln* Coal, dipping 70° S., but faulty. Its thickness averages 7 feet. Soft measures occur between it and the *Clarkson* Coal, with gentle dip. There are 6 feet of coal here. The tunnel runs from the Spohn to the Waln Coal.

The *Little Clarkson* dips from 20° to 25°. It has 3 feet of coal.

A supposed coal is said to occur in the interval.

The *Cellar* or *Stevenson* Coal is to be seen at an old drift on the roadside.

We now cross a hollow, and pass a small coal at a spring in the meadow, and another small coal just opposite the S. end of the North American Company's Mill; then the *synclinal axis* at the N. end of the mill.

The rocks are argillaceous flaggy sandstone; then a small coal repeated on a S. dip, and another small coal in a quarry N. of the sawmill.

North of a white house on the roadside there is a small coal which rolls and turns into a N. dip. This spot corresponds to the confused measures near the furnace on the opposite side of the valley. Over this small coal there is a shale, then sandstone and conglomerate in the basin at an angle of the road. The dip is gently S., to all appearance in the same sandstone. This is the conglomerate of the turn of the road on the W. side of Mill Creek near Summit Tavern.

On our line at the road is a drift in the Little Tracey Coal in position under the conglomerate. The Big Tracey Coal drift and shaft are at a ravine at the turn of the road. The dips are gentle, from 25° to 30°. A coarse sandstone overlies it.

It is thought by some that the Little Tracey of this side is the coal called the Clinton on the other, and the Big Tracey, the Peacock.

Between the Big Tracey and the Yard Coal is seen on the road a coarse conglomeritic sandstone. In a quarry of flaggy sandstone and shale there is a little coal in fault. The Yard Coal dips here 42° S. Next under this is the outcrop of a grey-speckled sandstone with yellow specks of oxide of iron, 10 feet thick; this bears for the slope belonging to the Clinton Coal on the W. side. Next N. of the faulty coal, opposite a small house at the bend of the road, is a coal, probably the true *Clinton* seam. It is that on which the slope is sunk at the Great Dirt-heap. It varies in thickness from 4 to 9 feet, and is thickest when dipping steepest. It is sunk upon through 70 yards in the slope. Under the Clinton, about 30 feet, there is a small 18-inch coal—the Perpendicular Coal of the W. side of the valley.

The South Diamond is in a drift S. of a white house (Mr Madison's), and the Green Park of the Furnace is there called the Diamond.

The North Diamond is the coal at the old engine-house on the W. side of the valley. It is 80 feet S. of the Little Hancock. A faulty small coal is in the slope. It is faulty at Wadesville (East Norwegian), but not at Oak Hill. It dips 25°.

An old drift at the S. end of the rubbish-heap is on the *Little Hancock*. This, on the West Norwegian, is a good coal of 20 inches thickness.

The *Main Hancock* Coal dips 25°; it is 3 feet thick, but faulty.

This ends the group of true Red-Ash Coals of the Mill Creek Valley.

On the W. side of Mill Creek Valley is the Yard Coal, here called by some the Clinton Coal.

A slope has been sunk on the Peacock Coal. It is worked at West Norwegian, but called there the *Clinton* Vein. The Green Park Coal of Mill Creek is that immediately S. of the furnace. It is apparently one of the Diamond group. It measures from 5 to 6 feet, and dips 45° S. Next is a dirt coal, not here opened, but it is opened on both Norwegian valleys.

The South Diamond, here so called, is next N. of the Green Park Coal. It is nearly perpendicular in the hollow, but only driven in 100 yards. Next N. is a coal worked by Nicholas many years since; it has a dip of say 45° S., with 4 feet of coal. Then the Big Diamond; thickness 5 feet; dipping 35° S. In this bed Richardson reached the bottom of a local narrow basin. The bed sent off a one-foot-thick leader, and rolled up into a N. dip. The mine was worked both E. and W., and good coal was taken from the S. dip, until a fault at both ends stopped them. The N. dip went up 4 or 5 yards, then turned over into a pinched S. dip—all faulty.

The Coals immediately above the Green Park Seam on Mill Creek are as follows:—

1. There is a 3-feet coal 90 or 100 feet above the Green Park bed, or 50 feet above the intermediate Little Diamond Coal.
2. A 3-feet coal shown by black dirt.
3. Another coal, about 7 yards below the Peacock, covered by a coarse sandstone, containing from 8 to 10 inches of iron ore, and upon this, the Peacock Coal, now mined by a slope. It is generally 7 feet thick.

The Clinton or Yard Coal is generally from 2½ to 3 feet thick.

Under the Primrose Coal on Mill Creek is the Black Valley or John Holmes Coal, from 3½ to 4 feet thick, carrying a little over it a small 6 or 8 inch coal. It was drifted and found in fault at 300 yards.

The Black Heath Coal occurs at Pinkerton's Breaker. It is only opened in black dirt at Pinkerton's Colliery, and seems to be about 5 feet thick, but was not worked at the period of our survey.

SINGLEY'S FARM.

Anticlinal J.—This axis forms a very sharp crest, the turn of the dip being on the N. brow of the hill, where the Clarkson Coal shows itself on the N. and S. sides of the axis-line in adjacent outcrops, the N. dip being steep. On the crest, and in the hollow next S., the dips repeatedly change, with crush and slight dislocation, of which there is a remarkable instance at the crest of the hill in the road.

1. The Lewis Coal crops out on a bench of the high hill S. of old Singley's house. It is 4½ feet thick. The gangway runs Eastwardly through the hill, and out to the next ravine. The dip is quite steep to the S. This coal is faulty for 300 yards towards the E., both above and below water-level; also on the adjoining property to the E. for 70 yards.
2. The Palmer Coal, which was worked out at Cwmbola, crops out about 300 feet N. of the Lewis Coal, but is not worked here.
3. The Chestnut Coal was worked on Mill Creek by Milnes below water-level, and by Spencer and Mason in a drift. It is from 3 to 4 feet thick, and crops out directly on the crest of the hill at the road. There was an iron stack upon it in the Orchard. It had been worked from Mill Creek 150 yards E. of this, or about 2000 yards E. in all.
4. The Clarkson Coal was opened on both sides of the crest axis. It is from 3 to 5 feet thick, and is worked from Mill Creek to the road at Singley's.

5. There is a small bed of about 18 inches thickness between the Chestnut and Clarkson coals; it was explored only on the S. dip.

6. A coal N. of the Clarkson bed, called the Robert Waln, dips nearly perpendicularly. It is 85 yards N. of the Clarkson, and is in the tunnel at Mill Creek: its usual thickness is from 4 to 6 feet, sometimes rather more.

7. The Stevenson Coal, dipping S.; about 4 feet thick; variable. The gangway runs only 36 yards.

8. A coal occurs in Singley's well, about 3½ feet thick; very good; dips S. It is 75 yards beyond the Robert Waln.

9. A coal dipping N. about 70°, 6 feet thick, just shafted on by Mr Singley. Very good Red-Ash coal, about 50 yards N. of the well.

10. A South-dipping coal, not very steep; 3 feet; worked only 150 yards: its outcrop is 150 yards from No. 9. The two would, of course, form a synclinal trough.

11. A coal dipping S., about 5½ feet thick; irregular: it has been shafted by Mr Singley. This crops out in the wood N. of the cornfield about 70 yards N. of No. 10. It is called here the Peach Mountain Vein. On the road, a few yards N. of the cornfield fence, the rocks dip steadily S.

12. A coal called the Bony Coal; Red Ash; is about 4 feet thick.

MILL CREEK (SOUTHERN PART) COLLIERIES.

Spencer and Mason's Drift on the Palmer Coal (*Singley's Chestnut Vein*).—The coal is about 3 feet thick throughout; dip 24½° S. The coal is good, in one solid mass, with no slate divisions. Above the coal is from 6 to 7 feet of fireclay—a loose poor top; above it is hard solid sandstone. The gangway runs E. about 2000 yards. At 1760 yards there is an air-stack: the breast measures 195 yards. It has been worked about twenty years.

Spencer and Mason's Spohn Coal Drift.—This is 44 yards N. of the Palmer; average dip 27° S., but varies greatly, sometimes being as steep as 50°, and sometimes nearly level. The coal averages 5 feet in thickness in three benches. The lower is 20 inches thick, and the best coal. The middle has from 20 inches to 2 feet of excellent pure coal. The upper has 15 inches of coarse coal. The gangway, when driven about 1000 yards E., reached a rock-fault which cut off all the coal except 6 or 7 inches. The drift was driven 140 yards through the fault, the coal varying from 7 inches to 4 feet in thickness. In 1853 it had been worked eleven or twelve years.

Snyder and Milnes' Lewis Coal Slope.—Down on the Lewis Coal, 125 yards from the top, and 100 yards below water-level, with S. dip of 35°, the vein averages 4½ feet in thickness. It has two benches; the lower is 2 feet thick, and the upper 2½ feet thick, with sometimes a little slate between. The top slate is good, and from 6 to 7 feet thick; on top of this is a leader with 18 inches of good coal; at the bottom is one foot of slate, then a 6-inch leader, and below this hard rock.

The gangway runs E. 1800 yards; for the last 500 yards the coal is faulty and crushed. From the bottom of the slope it was tunneled N. 215 yards. At 165 yards it is cut by the *Yard* Coal (?) only, 18 inches thick: they drove E. on it 1800 yards. The coal opens out to 2¾ feet in thickness, which it averages: it has a sort of soft fireclay top, with slate at bottom. In the tunnel is sandstone and conglomerate. At the end of the tunnel is the *Spohn* Coal, called the North Coal there. Driving E., the coal averages 3 feet in thickness. Faults are frequent; at the top is dirt, and sometimes Bony coal. This mine sends from 15,000 to 18,000 tons away.

Haven's Lewis Coal Slope.—This Slope was in 1853 down 185 yards, and 163 yards below the creek-level.

The coal was 7 feet of average thickness, in three benches: the top is 4 feet thick, with thin parting; the middle bench is 9 inches thick, with 18 inches of slate parting; and the bottom bench is from 15 to 20 inches thick. The top of the seam contains 2 feet of Bony coal: dip 32° S. on the first lift (100 yards); below that it is steeper. The end of the Western gangway is marked by a stack near the East Norwegian road.

There was nodular iron-ore 3 feet in thickness about 15 feet below the coal and sandy slates, and soft sandstone between it and the Slope coal.

There is a 3-feet leader N. of the Slope coal; then 40 feet of soft sandstone and conglomerate, dipping 40° S. to the *Spohn* Coal, which contains 8 feet of coal. *Above* the Lewis Coal is a bed, about 18 feet thick, of slaty sandstone, generally soft and crumbly, surmounted by a coal one foot thick.

The bearing from the tip of Haven's Slope to the tip of Snyder and Milnes' Slope is N. 72° E. by compass, showing the average strike of the Coal-measures.

From Haven's Slope to the office is 300 feet. Here is a quarry of ochreous sandstone, dipping 20° S. Above this are brownish and olive slates, continuing for 150 feet to a small bed of coal and slate $2\frac{3}{4}$ feet thick. Then yellowish and grey flaggy sandstone, weathering brown, S. dip 35°; and above this argillaceous slates, weathering brown, to the *Sandrock* Coal, 123 feet. Upon this lies a grey conglomeritic sandstone 15 feet thick. Its contact surface is very irregular; the thickness of the coal is about 3 feet: though not uniform, it contains not one foot of good coal. On the E. side it is 4 feet thick, and regular.

About 27 feet S. of this is the *Little Sandrock* Coal, and immediately under it are shales. Then 280 feet of argillaceous ochreous sandstone, slate, and shales, dipping, as above, to a small bed newly opened, above which is a coarse sandstone and Pea and Nut conglomerate, passing upwards into a flaggy grey sandstone.

The bearing of the outcrop of conglomerate on the E. side of the valley is N. 70° E. This rock, as exposed on the E. side, is a massive bluish-grey conglomerate containing blue slate, pebbles, as well as sparse ones of white quartz; dip 40° S. The white pebbles are seen running in narrow courses; over this is 20 feet of ochreous shaly slate, then 20 feet of conglomeritic sandstone like the preceding, 90 feet of arenaceous slate and shale, and ochreous or red sandstone on the surface, then 20 feet of coarse grey and brownish sandstone, dipping S. 40°. This is situated at the E. point of the hill.

PORT CARBON, MILL CREEK.

COAL-SEAMS IN THE GATE RIDGE ANTICLINAL FLEXURE.

The *Port Carbon Section* shows in the end of the hill a coal at 110 feet from the last stratum exposed at the road. It is the *Faust* Coal.

The *Rabbit Hole* Coal is at 250 feet. The Little Tunnel Coal comes above the Rabbit Hole, and

The *Main Tunnel* Coal occurs next. Under the Tunnel Coal is the hard sandstone of the hill of the Catholic Chapel.

The *Black Mine* Coal occurs between the Catholic Chapel and the road.

The *Lawton* Coal is next.

The *Belfast* Coal succeeds, and appears in a garden.

The Belfast Coal is seen again 57 feet S. of a stake at the edge of the street: the *Alfred Lawton* bed has a vertical dip: the anticlinal will be near the stake just spoken of.

The *Lion* Coal and the Alfred Lawton are probably the same bed, and on the W. side of Mill Creek appear at the anticlinal. The Lion Coal is called the Barn Coal.

To the Lion succeeds the *Ridge Gate* Coal, S. of the old engine-house. This has a dirt-bed on its W. side next S. of the spur, and is there called the Little Perpendicular. There is another coal just S. of a hard sandstone and conglomerate; it has no name, but it is also seen at an old drift on the W. side of the Pottsville Gap. The *South Gate* is about 100 feet N. of the last; and at about 200 further is the *Gate* Coal, within 50 feet of the stream. Again, on the road through the valley, the South Gate and the Gate are crossed. The former is 150 feet S. of the latter, with nearly vertical dips.

A careful revision of the ground occupied by the Lewis and Gate groups, leads to the following conclusions in regard to identity: that

The *Lewis, Gate,* and *Tunnel* Coals are the same:

The *Lower Lewis,* or *Little Spohn,* is the *South Gate* or *Blackmine* Coal:

Spohn, Palmer, Yard, Chestnut, of Spencer and Mason (iron air-shaft coal of Singley's Farm), are the same as the *Little Perpendicular Gate* Coal, or *Engine Gate,* and therefore the equivalent of *Selkirk.* This is sustained by the overlying conglomerate.

The *Little Tunnel, Rabbit Hole,* and *Nest* Coals, are the *Yard, Big* and *Little Sandrock* Coals.

Junction Tract (Property of North American Company).—The S. slope at the mines here is on the *Tunnel* Coal, which is identical with the Tunnel Coal of Salem Hollow. It was not worked E., except at Oliver's in Bear Ridge, and it is traced nearly opposite to New Philadelphia.

The first coal caught in Chillis' Hollow is the *Faust* Coal, which crops out near the tavern, while the Rabbit Hole crops out a little N. of the crest of the ridge of hard rock. The thickness of the Rabbit Hole at this locality is 2½ feet; and the distance between it and the Tunnel Coal is about 45 yards—the measures being chiefly sandstone.

The *Tunnel* Coal of this locality is about 4½ feet thick, and has upon its top about 8 feet of soft and bony coal and shale. It is generally overlaid with from 2½ to 3 feet of this matter. The dip is about 40° S. The gangways run E. and W. The coal lies in two benches, each bench containing from 2 to 2½ feet of coal. Between the two is a thin layer of dirt. The bottom bench contains rather the firmest and best coal. The distance from the Tunnel Coal back to the Blackmine bed is about 195 feet.

The Blackmine Coal is 4 feet thick.

At the Gin, a slope was sunk dipping to the E., the steepness of the dip increasing—this being just at the turn of the saddle. The coal appears to be in the position proper to the Selkirk Seam.

The *Randolph Tunnel,* in Sharp Mountain, is 365 yards long, and cuts ten coals: the thickest is 8 feet thick.

CHAPTER VII.

COAL-FIELD BETWEEN MILL CREEK AND THE WEST NORWEGIAN VALLEYS.

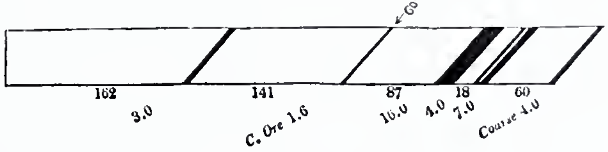
ANTICLINAL AND SYNCLINAL FLEXURES, AND THE COAL-BEDS CONTAINED IN EACH BASIN.

Proceeding, as in the last Chapter, to point out, before entering upon local details, the special parts of the Coal-measures which present themselves at the water-levels of the valleys, and in the hills between, in each particular basin formed by the several parallel anticlinal undulations of the coal-field, I shall commence my general description, as usual, with the most Northern belt, or that at the foot of Mine Hill.

Basin D E West, or that of Mount Laffy.—We have seen that on Mill Creek, the axis E in the Primrose Coal being an exceedingly feeble one, the basin before us contains at the water-level only the South-dipping strata belonging to the S. slope of the axis D, and that the coal-seams thus placed consist of all the upper White-Ash Measures, excepting the Skidmore bed, which is on the anticlinal Arch N of the Mammoth seam; and also the lower Red-Ash beds, the Flowery Field and the Primrose. But on East and West Norwegian the anticlinal E, or its near equivalent, becomes a much bolder wave, or has a much broader North-dipping flank. The basin *D E* exhibits, therefore, a true North-dipping belt, visible in the Primrose seam at and above the water-level on both the valleys. On East Norwegian the coals seen above the general water-level are on the N. side of the basin; the Mammoth Coal, with its overlying 7-feet-thick companion-bed, and a little over this the Black Heath Coal; then at a horizontal distance of 290 feet, the Black Valley bed, and S. of this 206 feet the Primrose Seam. On the N. dip no coal has been opened but the Primrose, which just at the anticlinal axis reaches a moderate elevation above the water-level of the valley, sufficient to enable it to be successfully mined on both its dips, or N. into basin *D E,* and S. into basin *E F.* At West Norwegian the general condition of things is almost precisely similar, the Primrose Seam being here entered also at the anticlinal axis, and wrought from Brown's old slopes in both basins. It would appear, however, that either the basin is deeper by a slight descent of its synclinal axis Westward, or that the denuding waters have left within it a greater thickness of the coal strata, for it contains in its centre two seams of coal above the Primrose bed—the Big and Little Peach Orchard Veins—not preserved at the East Norwegian. A glance at the Sections will make these relations clear.

The accompanying is a Section of the Old Mount Laffy Tunnel.

Fig. 170.—Mann and Williams' Tunnel, Mount Laffy, looking E.—1 *inch* = 200 *feet.*



Belt E G.—The very feeble anticlinal flexure F of Mill Creek, there gently undulating the Primrose Coal below water-level, appears to affect the strata as far W. as East Norwegian, where it lifts the Orchard Coals to the general upland, high enough for them to be denuded at the axis. On the West Norwegian the corresponding anticlinal F West, or L of the Western system, situated several hundred feet S. of the trend of axis F, is a flexure of greater breadth and height, and of much greater incurvation, its N. dips being nearly perpendicular, and its S. dips as steep as 40° in this quarter: therefore the belt E G includes two well-defined basins; whereas on East Norwegian it is rather to be viewed as one basin—that of Wadesville—with a roll or subordinate undulation 500 feet S. of its North-bounding axis E. On East Norwegian the anticlinal F does not quite bring the Primrose Coal up to water-level; whereas on West Norwegian, this coal, and its attendant 4-feet-thick underlying seam, span the axis F West in a well-defined steep arch. In the belt F G on East Norwegian, the lowest coal lifted to the day at the anticlinal G is that next beneath the Big Diamond seam; while on West Norwegian the effect of the supposed same anticlinal is to elevate a coal considerably lower—namely, the Little Diamond. It is a consequence of these conditions of the flexures, that while the Big Diamond, or the Dado Coal, is the highest workable bed of the Wadesville Basin, and the Primrose the lowest, the North Diamond, or Brown's Upper Coal, is the highest workable on West Norwegian, and the Primrose the lowest.

Belt G H.—The undulated belt G H,—viewing the anticlinal H as a persistent axis from East to West Norwegian, and the flexure H as dying out towards the Centre Turnpike Road,—is a complex or double basin on East Norwegian; and a single, or a very obliquely-crushed one, on the W. valley of that name. We know too little of the foldings of the strata in this belt on West Norwegian to pronounce with any certainty regarding the place of a folded synclinal axis, further than to state that it probably lies S. of the so-called Big or South Diamond Coal. At the valley of East Norwegian Creek, the coals called Big and South Diamond are separated by three intermediate thin coals. The South Diamond of that valley appears on both sides of the anticlinal axis H, and again just reaches the water-level at the axis H in M^cGinnes's boring. The highest coal in the basin *G H* is a seam next over this South Diamond bed; and the lowest on axis G a coal next below the Big Diamond, making in all seven South-dipping and two North-dipping outcrops in the basin, the synclinal axis lying very close to the anticlinal H.

Peach Mountain Basin.—The highest coal preserved in the synclinal bend of this wide and deep trough of the coal-field is the Peach Mountain Seam. This valuable coal has long since been entirely worked out above water-level from East to West Norwegian, and is by this time well-nigh if not completely exhausted down to its synclinal turn, even on West Norwegian, where the basin, there an oblique and compressed fold, is the deepest. The whole basin there, considering the anticlinal axis I as its true S. boundary, contains the outcrops of the three valuable coals—the Peach Mountain, Little Tracey and Big Tracey—besides a thin seam between the two former. The lowest coal lifted to the surface, on East Norwegian, by the anticlinal I, is the Big Tracey Seam, which is merely flexed at water-level by the anticlinal I into a very broad and flat swell on its N. dip. At the valley of Middle Norwegian the Peach Mountain basin appears to be more symmetrical than it is to the E. or W.: it contains the same beds as at East Norwegian, but is deeper and broader, holding originally a far larger amount of the Peach Mountain Seam. Here the Big Tracey Coal, retaining its name on the N. side of the basin, bears the name of the Chenoweth on the S. side, or where it dips North, to add to the confusion arising from the ignorance originally of the identity of the coals on opposite sides of the saddles and basins, and the consequent application of a separate name to almost every separate outcrop of this Big Tracey. Chenoweth Seam of the Peach Mountain basin is on the S. side of the anticlinal I, called the Clarkson Coal, while the Little Tracey, passing the same axis, is named the Pearson Seam, the Peach Mountain bed itself being called the Barclay Coal. (May not the Barclay Coal represent the small coal between the Peach Mountain and Little Tracey, and the Spohn Vein be the true representative of the Peach Mountain Coal ?)

Basin i J.—A steep and much-compressed basin, or oblique South-dipping trough, is visible on both East and Middle Norwegian valleys, between the steep anticlinal undulation I and the sharply-folded South-dipping anticlinal J. On East Norwegian, the anticlinal J exposes above the water-level the Big Tracey Coal known as the Clarkson north of the inclined anticlinal axis plane, and the Mason Coal south of it; *both*, however, dipping South. As a consequence of this structure, the Peach Mountain and Little Tracey coals, and probably one or two seams higher, lie in the middle of the basin, with both sets of outcrops dipping steeply Southward; the S. set belonging, of course, to the inverted portion of the beds. To identify either of the greatly crushed and faulty seams of this folded anticlinal with either of the well-known beds of the Peach Mountain Basin, is, in the present state of our knowledge of the ground, impossible. It might, perhaps, have been practicable twenty years ago, at the period of the most active operations of the East Delaware Mines, but in the present dilapidated and inaccessible condition of the old gangways, and the absence of deep slope or pit workings, the co-ordination of the seams is too uncertain to be ventured upon.

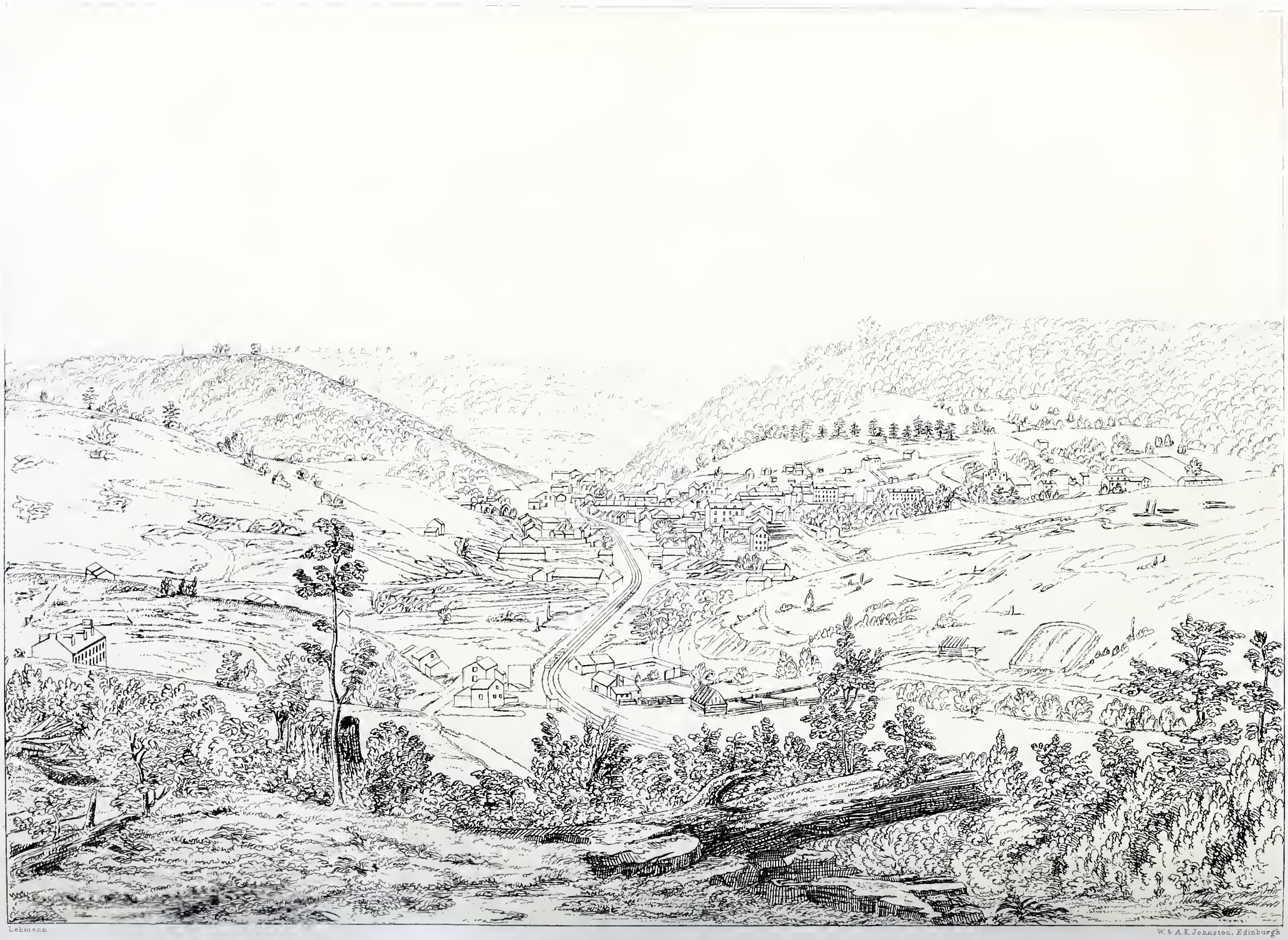
Crossing over to the Middle Norwegian, the anticlinal flexure J, already beginning to subside, has converted its inverted N. flank into a perpendicular one at the North American Company's mines in this valley. The uppermost coal-bed of the basin *i J* is the Spohn Seam, which, on the N. side, dips S. 30°, and on the S. side is perpendicular, and is called the Perpendicular Coal. It is squeezed from a thickness of $7\frac{1}{2}$ feet to one of 3 feet. This seam spans the anticlinal J at a high level, and becomes the well-known Lewis Coal of the adjoining basin *J K*, dipping again S. 30°.

Every effort to identify this important anticlinal flexure, which separates the Lewis and Spohn Coals on the W. side of West Norwegian, has hitherto proved abortive, though their identity has been established, it is thought, beyond question, by actual mining; the workings belonging to the two outcrops coming together a little E. of this valley being separated by merely a fault or jumble of the strata, the apparent running-out of the sharp axis J.

Basin J K, or that of West Norwegian.—Between Mill Creek and the West Norwegian Valley the synclinal trough included between the anticlinal axis J and that of the Gate Ridge K is broad, deep, and regular. On Mill Creek, as our Section of the strata at that valley shows, its central portion is nearly symmetrical, the N. dips not much exceeding the S. ones until we approach the Gate axis, when they become nearly perpendicular. The Gate Ridge anticlinal is there a steep normal flexure, its S. dips amounting to 45°, and its N. ones to 85°. Further W., between Salem Hollow and East Norwegian, and again at Pottsville, the North Branch of the curve becomes inverted, dipping indeed at even as low an angle to the S. as 40°; but this inversion does not extend quite to the synclinal axis, as may be seen by consulting our Section of the Middle Norwegian. Between Pottsville and the West Branch the inversion or folding at the anticlinal still prevails, as the West Branch Section indicates, but it is probably at its maximum near Pottsville. On the other hand, the synclinal flexure is rather more compressed or folded on the West Branch of the Schuylkill than on the Norwegian north of the town.

The uppermost coals of this Norwegian basin are those of the Salem group, or the highest Red-Ash group of the Schuylkill or Sharp Mountain basin. These have not been opened on Mill Creek, from the circumstance that they have too little breast above water-level, and being, moreover, in a shallow basin, could not repay the expense of mining by machinery, even should they prove thick enough. The pinched and folded condition of the basin at the N. foot of the Gate Ridge, renders it doubtful if the Salem group is present opposite East Norwegian, or at the mouth of the middle valley of that name; but there can be no doubt that the Sandrock group, or the coals next lower in the formation, are there embraced at the synclinal axis. This basin would thus appear to contain a very extensive series of the upper Red-Ash coal-beds—in other words, all the Gate group, the Sandrock group, and the Salem group; but it would seem, as already intimated, that it becomes somewhat less capacious as it ranges Westward. It is probable that the synclinal axis gradually rises in that direction, from the introduction of one or more anticlinals Q and Q Q of West Branch, and from an increased amount of folding of its South-bounding anticlinal K.

Basin K, or that of the Schuylkill at Pottsville.—This, the most S. synclinal trough of the coal-field, is at the same time the deepest and most capacious; its general structural features and its contents have been already so fully indicated, that a detailed description of it, beyond that which is given in the Sections and in the notes of localities which are to follow, is not called for. It may be expedient to mention, however, in observance of the mode of description of the other basins, that this trough contains the entire series of Coal-measures to be met with in the Southern coal-field, its S. border in the N. slope of the Sharp Mountain exposing all the lower or White-Ash coals, and its central or synclinal belt—occupied in part by the immediate valley of the Schuylkill—containing the very highest of the Red-Ash seams. It is not meant by this that every coal-bed met with in the region has an equivalent seam in the Sharp Mountain and Schuylkill Valley, for the coal-beds of the region are not all of them continuous, some, even very important and thick ones, thinning out altogether, while others replace them, seldom upon the same horizon. As no one locality or district assembles the several coals of the coal-field at large, we should not wonder that the local basin of Pottsville embraces, as it appears to do, a less number of beds than a general enumeration, covering all the districts of the region, exhibits. The Sharp Mountain side of the basin, from the upturned and squeezed condition of its strata, presents its coals in so crushed and faulty a condition as to render the identification of many of them almost impossible; and their unpromising condition for mining having prevented some of them from being fully explored, we are even left in some uncertainty as to their total number. The best conception of the contents of the basin, and the conditions under which its coal-beds exist, will be got from a careful study of the Norwegian Sections, and of the shorter Sections illustrating the Sharp Mountain. The synclinal axis, or central line of the trough, appears to be deepest between Pottsville and Port Carbon, for the Salem Vein worked at Port Carbon seems to basin out before going very far E.; and a careful tracing of the strata has satisfied me that there is a perceptible rise in the opposite direction, from the mouth of Salem Hollow to the Main Street of Pottsville at Silver's Row. The very bend of the synclinal flexure is well exposed in a hill-side cutting, just back of the street, in the rear of the row of houses mentioned, and the strata there displayed appear to be those which immediately overlie the South Salem seam of the Schuylkill, but at a higher level; the axis is also to be seen on the road by the river-side E. of Salem Hollow. Its direction by compass to Silver's



Lehmann

W. & A. K. Johnston, Edinburgh

POTTSVILLE IN 1840 FROM THE NORTH

Row is precisely S. 72° W. It is probable that the two coals in the synclinal axis at the Brewery lie in the hill above the street, and that the double crushed coal S. of Silver's Houses is the South Salem of Salem Hollow, and the crushed coal a little further S., in the quarry by the roadside, is the bed called the Upper Salem.

DETAILS OF THE SEVERAL COLLIERIES AND MINING LOCALITIES FROM MILL CREEK TO WEST NORWEGIAN.

SECTION ON EAST NORWEGIAN.

The old *Spohn* mine was last worked about twenty-five years ago. The coal had a very gentle S. dip of about 25°, and presented a sudden turn over to a N. dip, which was followed down a short distance from the outcrop. The Spohn Vein was said to be met with on the E. side of the valley, N. of the ravine, where there is an old shaft, now a *well with a windlass.* The coal, shafted at many places just S. of the ravine, is said to be the Little Coal between the Lewis and Spohn Coal. This would be the 3-feet coal found on the W. side of Mill Creek, between the Lewis and Spohn Coals, near Haven's Slope.

The Little Sandrock Coal is obscure on East Norwegian.

The Sandrock Coal crosses the railroad below the solitary white house on the E. side.

The (so-called) *Lewis* Coal of Belmont, or the coal next above the true Lewis Coal, occurs on the road just at the Spring. It is visible in an old drift on the W. side of the railroad.

The *Lewis* Coal is visible in a drift at the railroad; the ventilating-shaft is on it.

A small 2½-feet-thick coal, said to be the Perpendicular Coal of Middle Norwegian, is seen at an old drift; it was cut in the tunnel in Milnes and Synder's Colliery on Mill Creek, N. of the Lewis bed.

The *Spohn* Coal, or supposed Spohn, is at the turn of the carriage-road entering the hollow on the E. side of the railroad.

The *Palmer* Coal is nearer the head of the hollow. Another coal-bed is at the head of the hollow near the house; and still another on the flank of the hill which falls to the S.

There are two coals near the white house—first N. of the hollow—both opened by drifts. The more Northern of these is probably the Charles Pott, and the Southern the Palmer bed.

Near the old Breaker there is an old drift on another small bed.

The *Clarkson* Coal is the next in order, and over it there is another coal with no name; these, at Mr Mason's old mine, are 36 feet apart. It has been thought, from their approaching at their outcrops, that they unite in a folded acute anticlinal: indeed, there is little doubt that this is the place of the axis J. On the N. side of an outcrop of hard sandstone there is a small coal seen in an old drift.

The *Cellar* Coal crosses the road at the first double house at the E. side of the road, and shows a fallen outcrop at the foot of the garden. This is the Stevenson Coal of Mill Creek. The next visible coal is shafted upon at the old house on the E. side of the road, about 100 feet S. of the fork of the road. This dips N. about 40°, under coarse yellow sandstone. A coal crosses at the forks of the road.

The *Chenoweth* Coal is drifted into on the W. side at the S. end of the Delaware Company's old dirt-heap. It lies rather flat.

The *Big Tracey* Coal-drift is at the dirt-heap first S. of the Breaker on the W. side.

The *Little Tracey* Coal-drift is the first N. of the Breaker on the W. side, and appears again on the E. side at the road. This Little Tracey Coal dips under a coarse conglomeritic sandstone, 90 feet N. of an angle of the road, pitching 50° N.

Immediately N. of this rock is the synclinal axis, and then occur S. dips, in which, in the bed of the ravine, is the *Peach Mountain* Coal. The same rock is seen with a S. dip of 40° at an angle of the road on a ridge of the valley of Mill Creek; the Little Tracey Coal-drift is in the basin immediately under it, and its outcrop is on the road 100 feet N. of the turn of the road, and 50 feet N. of the coarse rock.

Jones and Mason's Slope Colliery, at the head of East Norwegian, above Wadesville, has two slopes, one on the N. the other on the S. dip of a saddle in the *Primrose* Coal.

The *North-dipping Slope* is down 40 yards; its average dip is 25°; its average thickness is 4 feet; it has two benches, of 2 feet thickness each; the top and bottom slates are good.

From the bottom of the slope the gangway ran E. about 200 yards. At a short distance from the slope, on the E. and W. gangways, other gangways run N.: their length is not certain. The Primrose Coal is thus seen to saddle at the top of the N. slope, and to basin at the foot.

In the *South-dipping Slope*, which in 1853 was down 108 yards, the dip is 25°, and rather irregular. New gangways were just starting E. and W.

About 500 yards N.W. of the Primrose Slopes there is a slope on the Big or Mammoth Coal, down on the S. dip 155 yards; the dip is about 35°. The coal was about 18 feet thick, and in three benches, with one parting of slate of 3 inches thick. From the bottom of the slope, gangways run E. On the top of the Big Coal lie 7 feet of slate, and on the top of this is the Seven-feet Coal, which is worked on the same slope with the Big Coal. At the foot of its slope is another gangway running E.

S. of the Primrose saddle, in the same hill, is a basin of the Orchard Coals (see Section); and still further S. these form another saddle. It is said that, 300 yards E. of the slope, the Primrose saddle dies away—soon, however, to rise again in nearly the same line.

MIDDLE NORWEGIAN.

North American Company's Mines.—At this colliery the Lewis Coal, one of the more valuable of the Red-Ash series, has long since been wrought out above water-level, and is now mined by a slope and steam-power. The bed is between 7 and 8 feet thick: it dips 30° S. 18° E. About 800 feet N. of the Lewis is the so-called Perpendicular Coal, which is believed by some to be merely the N. dip of the Lewis bed, on the opposite side of the anticlinal axis J; indeed, if I mistake not, they have been proved to connect towards West Norwegian by mining. It is, however, but 3 feet thick at Middle Norwegian, being evidently greatly pinched by the compression of the strata, so usual on the N. side of a steep anticlinal flexure. Nearly 400 feet N. of the outcrop of the Perpendicular Coal is the outcrop of the Spohn bed, which dips 30° S. This coal, believed by some persons to be identical with the Lewis, through the Perpendicular bed with which it is said to basin below water-level, is about 7½ feet thick. Beneath the Spohn lies the Barclay Coal, 5 feet thick; the Pearson Coal, 3½ feet thick; and the Clarkson Coal, 7 feet thick, all dipping towards the S. at 30° or 35°. To the N. of the anticlinal axis I, these coals reappear in the Peach Mountain Basin, but under the different names already mentioned.

WEST NORWEGIAN.

The Pea-conglomerate N. of the *Diamond* Coal of West Norwegian is certainly like the conglomerate beneath the Big Diamond Coal of Silver Creek, Zachariah's Run, &c., and I regard it as the same rock. It is seen in the point of a hill or spur N. of the Old Diamond Slope chimney, West Norwegian.

The dense Pea-conglomerate, visible at Mount Laffy under the Primrose Coal, is to be seen again on West Branch, just N. of Morgan Brace's Breaker. There can be no doubt that Morgan's Coal of West Branch is identical with the Primrose of West Norwegian, Mill Creek, &c. It seems most probable that the main anticlinal of Mount Laffy is that of the Oak Hill Coal of West Branch.

Charles Miller's Slope on Mine Hill.—Down on the bottom-slate of the Mammoth or Big Coal, the S. dip averages 55°. The Big Coal is 6 feet thick; immediately on the top of this is a very hard rock, from 3 to 6 feet thick, then a 7-feet coal, then 7 feet thickness of slate and rock, to a 12-feet coal called the Seven-feet Coal, the same as the Black Heath of Heilner's Tunnel, all worked by a slope. (Though this is the slope referred to in our notes on East Norwegian, derived from Mr Davis, in some points the statements disagree.)

Mount Laffy Tunnel enters N. into Mine Hill; the length of breast in the Big Coal is 60 yards, the dip of the beds is about 45°, but it becomes flatter in going N.

Brown's Colliery.—The *Primrose* Coal has been actually traced hence W. about 1100 yards; this would be nearly to the swamp. It has been worked on the upper level that distance, and the air-holes may be followed nearly to the swamp. The average thickness of the coal is 9 feet. When sound, it has eight benches. In its lower part occur 3 feet of *Red-Ash* Coal, which, when not pure and sound, is all dirt; above this there is a 15-inch layer of bony coal, and over this are six benches of Pink-Ash coal. The two, mixed, make a good Red-Ash coal.

The N. and S. dips of the Primrose Coal, at the water-level, are about 150 feet apart, but at the road-level, 60 feet higher, they come together. The N. pitch at water-level is 80°, the S. pitch 40°. The Orchard coals overlie the Primrose on the axis, at an interval of 140 to 150 feet, and back from the valley on both sides are saddled over by the conglomerate. The axis of the Primrose flattens towards both the E. and W.; towards the W. it disappears in about 400 yards, but it continues a greater distance Eastward. It is cut just at the mouth of the Mount Laffy Tunnel. Below the Peach Orchard Coal there is a slaty floor of 18 inches thickness, and below this 12 feet of hard blue sandstone, and below this again 40 feet of slate, including two courses of iron ore. Underneath these there is a bed of massive ore locally 18 inches thick, next slaty rocks, hard and blue, 30 feet, and then solid blue sandstone 12 feet thick, and finally, the slate above the Primrose. Over the Orchard is first fireclay, then slate with sulphuret of iron, then a little blue and ochreous slate. The distance between the two

Orchard coals is 45 feet. The lower Orchard bed extends, at a pretty steep pitch, to about 50 feet below water-level. The dip of the rocks in Brown's Shaft is about 24° S. The N. dips of the Orchard Coal come in N. of the ravine opposite the shaft. The North Diamond forms a basin, in the centre of which stands Mr Brown's house, just at the level of the turn.

The Big or Cockle Diamond is a somewhat bony but good coal, 7 feet thick; it is worked at Miller's Phœnix Slope, on West-West Branch.

The true Little Diamond (if correctly identified) is worked under Spencer's Breaker, near Minersville, also on Wolf Creek, and on West Norwegian, where there are from 2½ to 3 feet of good coal in it.

Peach Mountain Coal of West Norwegian—(Delaware Mines).—The upper slope in 1853 was sunk about 200 yards. The coal had been worked Westward from the Old Slope one mile, and from the New Slope 90 yards more. At the New Slope the bed dips S. from it at an angle of 45°, then more steeply; and still deeper down it flattens off to 45° again.

The basin is thought to descend gently Eastward. At the East Mines, on the contrary, the basin descends towards the W., as the dimensions of the trough opposite the two slopes there clearly prove. In the one, the length of slope to the synclinal turn or bottom of the basin is only 150 feet; in the other, 400 yards further W., with a somewhat more gentle dip, it is 300 feet, the North-dipping branch of the bed being about 70 feet. The distance between the N. and S. outcrops of the Peach Mountain Coal, 1000 yards W. at the railroad, is one-fourth of a mile.

The Peach Mountain Coal on the S. side of the basin, or the North-dipping perpendicular outcrop, has been worked more than 700 yards E. from the West Norwegian Railroad by Mr Reed. It is 300 yards from the North-dipping Spohn to the last-dipping Peach Mountain. There is no coal of any importance between them. At the turnpike, the Spohn is 150 yards from the North-dipping Peach Mountain.

The coal at the slope is the *Dill*, the upper bench of which is from 4 to 6 feet thick, whilst below this is a hard slate, of from 6 inches to as many feet in thickness, and beneath this an inferior coal from 2 to 3½ feet thick. At the E. mines, these parting-slates varied rapidly in the same gangway, thinning away to nothing, and then again being many feet in thickness. The coal of the S. dip is much better than that of the N. dip. The Dill Coal is not 100 feet N. of the Peach Mountain gentle S. dip.

George Miller's Works.—A perpendicular *shaft* is here sunk to the *Lewis* Coal, the 85 yards descent giving a lift of 140 yards to the old water-level of the coal, and 30 yards more to the outcrop, which is on the brow of the hill to the Northward. The dip of the Lewis is from 31° to 32° S., and regular; its average thickness is 6 feet. From the valley a tunnel runs N. under the end of the hill about 350 yards to the Lewis Coal. This coal lies in three benches: the bottom one has 2½ feet of clear prime coal; the middle a band of slate from 2 to 9 inches thick, and a coal one foot thick; and the upper bench 2½ feet of coal, with a parting of shelly coal.

The pillars were being worked out in 1853. The coal had been worked both above and below water-level from this shaft 600 yards E., and up to the line of the North American Company. Above the coal lies a bed of slate 15 feet thick, and then a considerable thickness of soft grey and greenish sandstone-ore, weathering ochreous, and passing at times into argillaceous shaly sandstone. From the bottom of the shaft there descends a slope on the coal 100 yards deep. The seam is cut off on the E., about 200 yards from the bottom of the shaft, by a rock-fault. The gangway near this turns a little towards the N., about 10 yards in 100. The plane of the dislocation runs a little E. of N., and dips towards the N. at about 85°. Beyond the W. limit of the tract the coal is again cut off by a rock-fault. The Lewis Coal, although sought for, has not been proved on the W. side of the West Norwegian Valley.

The Spohn Coal, which has been wrought a short distance N. of the Lewis with like dip, is also cut off by the fault first mentioned, and has not been traced to the opposite side of the valley.

The following is a detailed section of the Coal-measures in the Sharp Mountain, commencing from the top of the main Seral conglomerate, the horizon of which is, however, rather arbitrary.

SHARP MOUNTAIN COAL-MEASURES, POTTSVILLE.

(See General Section, Plate II.)

No.		Thickness. Feet.	Thickness. In.
1.	The first belt of coarse conglomerate beneath the lowest coal; pebbles, chiefly quartz, many of them as large as a hen's egg, ...	17½	0
2.	A grey conglomeritic coarse sandstone, .	8	0
3.	A coarse grey argillaceous grit, with specks of coaly matter and impressions of coal-plants, ...	1	7
4.	Grey silicious sandstone, . .	6	5
5.	Micaceous and slightly argillaceous flaggy sandstone, with some conglomerate, .	4	0
6.	Coarse grit, irregularly laminated, .	8	0
	Hiatus. An absence of definite outcrops from the foregoing stratum to the Plumbago Coal, but the fragmentary matters indicate coal-shales, and probably a thin and soft bed of coal, . . .	139	0
7.	*Plumbago Coal,* 1.—This coal, as already intimated, is much crushed, and therefore but little reliance can be placed upon any local measurement of its size. A lump of the coal crumbles under slight pressure into thin glossy flakes, having an unctuous feel, and a lustre resembling that of plumbago. An argillaceous bed S. of the coal—its original fireclay floor—is generally in a crushed condition. The shaly matter is mingled with finely-comminuted coal, and resembles the substitute for plumbago called *Blackpot,* .	7	0
8.	A dark laminated sandy top-slate, with coal fossils; it is much fractured, .	19	6
9.	A bluish argillaceous shale, but little laminated, ...	35	6
10.	A bottom-slate on sandy fireclay, like No. 9,	5	0
11.	*Coal* 2.—Crushed and soft, . .	1	6
12.	A top-slate, ...	4	0
13.	Bluish shale, approaching a fireclay, .	12	0
14.	Hard grey sandstone, . . .	6	0
15.	*Coal* 3.—A coal, and its thin bottom-shale crushed together, . . .	2	6
16.	A thin bed of roof-slate.	—	
17.	Blue argillaceous shale, or under-clay of coal, ...	15	6
18.	*Coal* 4.—A coal-bed, . . .	7	0
19.	The roof-slate of Coal 4, . .	2	6
20.	Coarse micaceous sandstone, slightly argillaceous, ...	21	0
21.	Hard grey gritty sandstone, . .	65	0
22.	Blue shale, soft and crushed, . .	2	6
23.	*Coal* 5.—A soft crushed coal-bed, containing a little sound coal in its middle layer,	7	0
24.	Compact blue slate and shale, . .	56	0
25.	Coal shale, with impressions of Stigmaria,	2	0
26.	*Coal* 6.—A coal-bed, . . .	2	0
27.	Slate, blue and compact, . .	10	0
28.	Shale, soft, crushed, and shivery, .	10	0
29.	Hard blue argillaceous sandstone, .	62	6
30.	Alternation of beds of sandstone and slate,	30	0
31.	Coarse blue argillaceous grit, . .	15	0
32.	Carbonaceous slate, . . .	20	0
33.	Bluish coaly slate, . . .	7	0
34.	Coal shale, ...	4	0
35.	*Coal* 7.—Coal and bruised shale mingled,	15	0

No.		Thickness. Feet.	Thickness. In.
36.	Black slate,	4	0
37.	Obliquely laminated argillaceous sandstone,	4	0
38.	Blue and grey argillaceous grit,	10	0
39.	Fine-grained blue sandstone,	13	0
40.	Shale, soft and contorted,	9	0
41.	*Coal* 8.—A coal-bed, crushed and soft,	1	0
42.	Laminated dark-blue roof-slate,	9	0
43.	*Coal* 9.—A coal-bed,	1	0
44.	Fine-grained argillaceous sandstone,	76	0
45.	No distinct exposure,	9	0
46.	Grey ferruginous sandstone,	5	0
47.	Blue coal-shale, sandy fireclay,	8	0
48.	*Coal* 10.—A coal-bed, not in a sound condition,	16	0
49.	Dark roof-slate, with fossil ferns, &c.,	1	0
50.	Coarse blue argillaceous sandstone,	10	0
51.	Blue shale and slate,	2	0
52.	Micaceous sandstone,	14	0
53.	A more argillaceous micaceous sandstone,	30	0
54.	Argillaceous, arenaceous, and micaceous sandstones,	51	0
55.	Coarse grey sandstone,	2	0
56.	*Coal* 11.—Coal and shale; the thickness of the coal-bed itself not ascertained, both	? 24	0
57.	Shale, with Calamites,	20	0
58.	Coarse grey sandstone,	4	6
59.	Alternation of shale and sandstone,	8	0
60.	Argillaceous grey sandstone,	4	6
61.	Grey sandstone,	16	0
62.	Shale and sandstone,	15	0
63.	Coarse arenaceous sandstone,	30	0
64.	Greenish shale,	4	0
65.	Greenish argillaceous sandstone,	9	0
66.	Grey and greenish grit,	10	0
67.	Coarse argillaceous sandstone,	8	0
68.	Conglomerate and coarse grit, with argillaceous cement,	19	0
69.	Olive-coloured slate,	4	0
70.	Coarse argillaceous sandstone,	12	0
71.	Blue slate,	1	0
72.	Grey shale and slate,	28	0
73.	Coarse argillaceous sandstone,	5	0
74.	Fine-grained argillaceous sandstone, *much crushed.* Great synclinal axis or line of change of dip, marking the deepest part of the Sharp Mountain Basin. Here the strata change from their steep inverted dip of 85° near the axis, to a moderately gentle Southern dip at the base of the mountain, just behind Silver's Houses, or opposite the E. and W. reach of the Schuylkill.		

Where an attempt is made to recognise the particular coals of this Pottsville group at the other natural transverse sections of the Sharp Mountain, it is found impossible to identify more than a portion of them. This arises from the circumstance that their overturned and shattered condition has prevented their being extensively opened at any of the other localities between this spot and Tamaqua on the one hand, and the Swatara Notch on the other, and from the fact that, even in the vicinity of Pottsville, they have not, from the same cause, been followed far enough along their outcrops by experimental shafting, to permit us to trace them continuously to their other exposures.

An examination of the Section above given of the Coal-measures of the Sharp Mountain discloses only eleven coal-beds of all dimensions, from a thickness of from 1 to 15 feet. As this is just one-half the number of the seams separately identified and mined on Mill Creek, distant only from 2 to 4 miles, we are compelled to infer, that from the squeezed and faulty condition of the strata in the flank and at the base of Sharp Mountain, between Mount Carbon and Pottsville, some of the beds have never been detected. It is probable, indeed, that a few of them are lost entirely at the surface in the one or more longitudinal dislocations, of which there are strong indications between the synclinal axis of the basin and the side of the mountain. That this S. side of the basin does actually contain more than the eleven coals discovered at Pottsville, is implied by the fact that the Randolph Tunnel further E. in Sharp Mountain, entering some distance to the S. of the synclinal axis, cuts itself no less than ten notable coal-seams. If I mistake not, there are at least fourteen beds recognisable between the base and upper slope of the mountain S. of Port Carbon. In a future chapter, devoted to a general comparative survey of the coal-beds of the basin, it will appear that the district of Mill Creek contains a greater total number of separate beds than any other.

COALS IN THE NORTH SIDE OF THE SHARP MOUNTAIN BASIN.

Between the folded anticlinal flexure of Gate Ridge and the synclinal bend of the Sharp Mountain Basin at the Schuylkill, the stratification is very regular from Mill Creek Valley to that of the Norwegian at Pottsville; the dip is uniformly S. as steep as 45° near the anticlinal axis, but gradually subsides to 35° and 30°, as we approach the middle of the trough. The total number of coal-beds is thirteen, eleven of which have names; these in ascending order, or Southward from the Gate axis, are—1. The Alfred Lawton; 2. Belfast; 3. Selkirk; 4. Black Mine; 5. Tunnel; 6. Rabbit Hole; 7. Faust; 8. North Salem; 9. Weasel; 10. Salem; 11. South Salem. Their dips, distances, and thicknesses are given in the Sections. The accompanying cut represents the state of things along a line of section between the summit of Lawton's Hill or Gate Ridge and the Schuylkill through the ravine called Salem Hollow, a little E. of Pottsville.

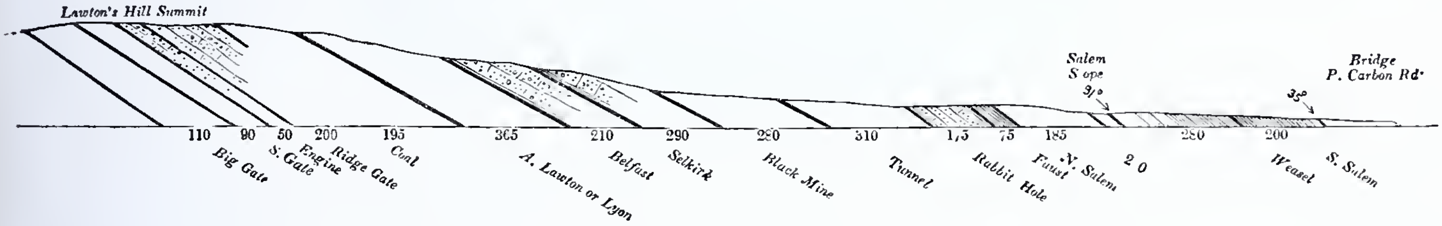


Fig. 171.—Section of Salem Hollow, looking E.—1 *inch* = 400 *feet*.

Plate II. of the Sections of the Anthracite Basins represents these coal-beds as they are seen at Pottsville, on the E. side of the Norwegian Valley, from the N. foot of the Gate Ridge to the synclinal axis; and another Section on the same Plate displays their positions on the other side of Salem Hollow, opposite the valley of the East Norwegian. A correct view of the end of the Gate Ridge on the E. side of the valley at Pottsville is given in our woodcut (fig. 172). A little dimple or depression in the face of the hill shows the superior force of the excavating waters upon the crushed strata immediately at the anticlinal axis; the light dotted lines indicate the dips of the coal-beds on the two sides of this oblique saddle. (See Section of Gate Ridge.)

At Pott's Colliery, west of Pottsville, the distance from the Tunnel Coal to the Rabbit Hole bed is 60 yards, from the Rabbit Hole to the Faust it is 40 yards, and from the Faust to the Salem it is 95 yards. These horizontal measurements disagree widely with those of the corresponding strata at Salem Hollow. The discrepancy is due in part to a difference of inclination, but in a yet greater degree to an actual change in thickness of the dividing rocks, especially the sandstones.

Salem Colliery, Salem Hollow, East of Pottsville.—This mine in the Salem Vein is interesting as being the deepest slope working in the coal region, and as belonging, moreover, to the uppermost of all the workable seams. In 1853 the length of the slope was 1030 feet; the average angle of dip is S. 35°. At that time there were five lifts, and at the foot of the slope the E. gangway was 200 yards long, and the W. gangway 150 yards. The other lifts, or intervals between gangway and gangway, had been mined E. to the Port-Carbon Salem Colliery, and W. beyond Pottsville. This coal-seam exhibits a thickness of from 2 to 3 feet, but it is variable: the coal is usually in one bench, and beneath it is a seam of soft powdery coal (or dirt) one foot thick. The slope descends in a direction S. 20° E., and the bottom of it is vertically under the river.

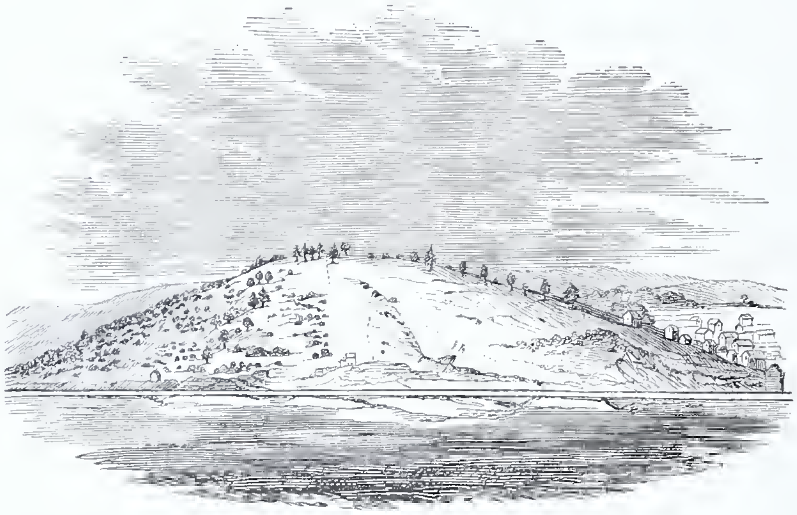


FIG. 172.—End View of Gate Ridge (Lawton's Hill), Pottsville, looking E.

CHAPTER VIII.

ANTICLINAL FLEXURES OF THE COAL-FIELD BETWEEN WEST NORWEGIAN AND SWATARA VALLEYS TRACED IN DETAIL, WITH THE COAL-BEDS ALONG THEIR AXES.

AXIS OF SWATARA FALLS AND PRIMROSE HILL, OR ANTICLINAL M.

THE most Northern clearly-traced anticlinal of the W. part of the Pottsville Coal-field is that of the Swatara Falls, where the flexure elevates the Lower Great Conglomerate of our Coal-measures. There is another axis, L, of Broad Mountain, still further N., but it is too little known to merit a more detailed description than that which it has already received. That of the Falls is a well-marked axis, having steep N. and comparatively gentle S. dips, and is plainly marked in the topography of the country by the crest of the ridge prolonged from the Swatara eastward, as far as the valley of Muddy Creek.

Traced through the high crest alluded to, it gradually sinks until we descend into Muddy Creek Hollow, where the anticlinal passes some hundred yards S. of Morgan's Tunnel.

Still Eastward from this, an anticlinal, either the same one prolonged or another replacing it, and nearly continuous with it, ranges a little S. of the mouth of the York Tunnel. This may be traced to West-West Branch, where it is seen as a low and narrow arch, affecting the Little Diamond and adjoining coals of Patton's Valley near Britton's Store, from whence it passes through the N. part of Primrose Hill, being the Northern of the two flexures which turn the Peach Mountain (Kantner) Coal in M^cDonald's Colliery, and there indicated by the N. ventilating-stack.

Traced Westward, it will be found to cross the ravine of Middle Creek N. of the W. head of Fisher's Basin. Rising and separating the conglomerate which saddles it into two outcrops, it at last lifts to the surface, high on the S.W. plateau of the Broad Mountain, the upper beds of the Umbral red shale.

Turning our attention to the strata exposed on the back of this great saddle at the water-level of the main transverse valleys, we find that in the gorge of Middle Creek it lifts to the day the lowest main bed of Egg-conglomerate, and even some of the inferior conglomeritic strata.

On Swatara, the whole upper half of the Seral conglomerate, embracing both the upper and lower main Egg-conglomerates, and a small coal between them, rises above the water-level in the centre of the finely-exposed arch.

At the valley of Muddy Branch, the White-Ash Coal, so called (Bast's White-Ash Vein), comes down to the water-level, closing its two outcrops together to arch over it, or lap across it. Just E. of this point, the Grey Ash, or next superior coal, in like manner sinks under the water-level, and its gangways wind round the axis from S. into N. dips.

Still further E., at a point a few hundred feet E. of the York Tunnel, it deflects or winds the gangway of the Big Diamond Coal worked in from the water-level of the West-West Branch, from its place on the N. dip of the basin S. of it, to a position on the N. dip of the basin N.

Dipping very gradually E. towards the West-West Branch, the axis there allows the Little Diamond and two subjacent coals, previously on its flanks, to fold or arch across it at the water-level of the valley near Britton's Store. (See West-West Branch Section.) As the more Northern of the two adjacent saddles in the Kantner Peach Mountain Coal of Primrose Hill, this axis is discernible in the windings it gives to the gangways of that coal the whole way as far as the valley of Wolf Creek, where it probably affects the South-dipping portion called the Spencer Vein, in a low roll a little S. of the foot of Spencer's Slope. It is visible, indeed, in a narrow space of N. dips on the road from Minersville, leading along the E. side of Wolf Creek Valley. It seems to expire altogether before reaching the valley of West Branch.

At the West-West Branch this anticlinal axis lifts the Big Diamond Coal, on the W. side of the valley above the water-level, but it does not bring it quite to that elevation on the E. It is there the main anticlinal of the broad swell of Primrose Hill, and where this hill assumes its height E. of the valley, it contains on the back of this saddle, in unbroken concentric arching, all the Coal-measures between the Big Diamond under water-level, and the Cockle's Red-Ash or Oak-Hill Coal of Wolf Creek (the Peacock of Mill Creek ?) This Cockle's Red-Ash Vein, the highest which completely arches the axis, has been here mined entirely across it in Britton's workings. The Little Diamond, which is two coals higher in the series, does not saddle it in the hill, but is parted into two outcrops. The Cockle's Red-Ash Coal is that of the N. or New Slope of the Phœnix Mines, while the Little Diamond is the coal of the S. or Old Slope, but between the anticlinal now described and these outcrops of the slopes there is interposed another axis, N, to be traced presently.

Advancing Eastward from West-West Branch, the axis continuously sinking, and the hill still swelling in height, we find that the Little Diamond Coal soon rolls over the arch. Further on, when we ascend to the summit of Primrose Hill, even the Peach Mountain or Kantner Coal unites its outcrops, and laps across and round the axis. This is near the little village of Primrose Hill. This axis is the main anticlinal, that previously described being but a roll on its N. flank. They are closely approximated, and are of nearly equal force, so that they impart a double undulation to the strata, the effect of which upon the working of the mines, in the Peach Mountain Vein, is to turn its gangways, at the different successive levels, in a double or arcuated winding course, sweeping from S.E. into E. dips, and finally into N. dips. This axis and its companion form the quite feeble arch in the rocks just S. of the Spencer outcrop of the Peach Mountain Coal, visible on the road on the E. side of Wolf Creek Valley ; beyond that point neither of them is discernible.

AXIS OF THE DRIPPING ARCH AND PHŒNIX MINES, OR ANTICLINAL N.

In the W. quarter of the coal-field, the next more Southern anticlinal first indicates itself on Middle Creek of Swatara, forming there the S. boundary of the W. end of Fisher's Basin. The exact position of this axis is the bold and picturesque arch of the upper Egg-conglomerate at the Dripping Spring. Here the flexure is a very gentle one, the N. dips of the S. side of Fisher's Basin here not exceeding 10°. In ranging Eastward the anticlinal develops itself into a bolder flexure, with steeper inclinations on its flanks.

The maximum compression of the wave appears to be in the neighbourhood of Muddy Branch at the Heckscher New Mines, where the N. dips amount to 75° and the S. to 30°. From this point Eastward, still slowly dipping in level, the saddle gradually flattens, but the N. dips connected with it do not disappear ; or, in other words, the axis does not cease until we reach the West Norwegian.

Westward from Middle Creek it is not traceable in distinct N. dips for any considerable distance, but its influence is felt in spreading wider the flat or gently Southerly dip of the strata, and in expanding the S. slope of Thick Mountain, N. of Donaldson, into a broad elevated plateau. This flattening of the anticlinal lifts and smooths out of course the synclinal flexure of Fisher's Basin, which soon ceases altogether before reaching the meridian of Donaldson, but is replaced in the same range by moderate S. dips of from 15° to 20°, all across the mountain.

The effect on the Coal-measures of this axis, tracing it progressively Eastward, is, at Middle Creek, to place the upper layers of the great upper Egg-conglomerate, supporting the lowest workable White-Ash coals, the Ten-feet Vein, so called, &c., at an elevation of about 100 feet above the stream in the bottom of the gorge.

On Swatara this arch appears with maximum dips of about 45°, separating Fisher's from M^{c}Creary's Basin, and it there divides by several hundred feet the two outcrops of the Grey-Ash coal, the lowest vein which is worked. Between the denuded back or top of the arch and the water-level of the valley, only the coarse sandstones and Pea-conglomerate beds, just over the main upper Egg-conglomerate, are exposed through a height of some two hundred feet, but the Egg-conglomerate itself does not quite rise to the bed of the valley. (See Section on Swatara.)

At the valley of Muddy Branch the Heckscher Red-Ash Coal is parted at the water-level into two outcrops several hundred feet asunder, but the Grey-Ash, or next subjacent coal, does not reach the surface of the valley. It is not easy to trace this axis by actual exposures to the Eastward of Muddy Branch, for as yet no North-dipping strata have been discovered in the line of its prolongation until we reach the West-West Branch. It, however, corresponds so closely in position with the anticlinal of the Phœnix Mines on that stream, or with the Peach Mountain and Kantner axis, north of Minersville, that I am disposed to look upon them as one identical line of flexure. This last-mentioned E. division extends with apparent continuity from the West-West Branch to the West Norwegian at the Green Park Tunnel.

To recapitulate the chief facts known respecting this axis, it may be briefly described as that of the Phœnix Tunnel and of Heckscher's Red-Ash Colliery. At Minersville it lifts to the water-level the Little Tracey Coal, and it parts the Kantner and Peach Mountain coals. At the Phœnix Tunnel it carries over it at water-level the Phœnix North-Slope Coal, or Cockle Red-Ash, or Mill-Creek Peacock Coal. On the W. side of West-West Branch it has lifted above water-level the Bast Big Diamond, or Phœnix North Coal, and Phœnix South Coal. At Muddy Branch (Otto Lands) the Heckscher Red-Ash Coal is parted into two high outcrops by it. On the Swatara it lifts to water-level the sandstones overlying the upper main Egg-conglomerate, sustaining in two sets of outcrops, high on the flanks of the saddle, the three lower coals of Fisher's Basin and M^cCreary's S. dips: viz., the Grey Coal, the Ten-feet Donaldson, and Donaldson Big Coals. At Middle Creek it elevates to 100 (?) feet above the water-level the top beds of the great upper Egg-conglomerate, saddled there by the same coals above mentioned. But at Donaldson Mines in Thick Mountain this anticlinal is no longer seen, the basin N. of it having been lifted or flattened up, and indeed replaced, by gentle S. dips, varying from 15° to 20° S. all across the mountain.

BASIN *M N*, SOUTH OF SWATARA FALLS AXIS—PART OF FISHER'S BASIN.

On the Swatara, and for some distance Westward, as far at least as Middle Creek, this basin still retains above the upper Egg-conglomerate three several coals, the two higher of which are valuable beds for mining. The bottom or synclinal centre of this basin seems to rise going Westward for a certain distance, and then to descend again towards Middle Creek, falling there to a level only a little higher than that which it has on the Swatara. The probability is, that it is highest somewhere near the watershed between these streams.

Recent explorations make it almost certain that none of these coals above the upper great Egg-conglomerate pass Westward in this basin beyond the ravine of Middle Creek; but a lower series of White-Ash seams, five in number, have been opened on the S. side of the Swatara Falls anticlinal, or N. side of this trough, on the flank of the mountain, at a point considerably to the Westward. How far these extend is not yet known, but the sandstone measures of the flat summit of the Thick Mountain, N. of Donaldson Mines, give but little indication of their presence there. Of the five coals here spoken of, the two lower ones are each of them but 6 inches thick; the third appears to be in the shafts on its outcrop, about 7 feet in thickness; the fourth is 6 feet thick, but contains very little good coal; and the fifth, or highest, is 2½ feet thick of coal, rather squeezed and soft; there is a conglomerate rock both above and below this latter, but its outcrop is some 600 feet N. of the main upper conglomerate, or "Big Rock." The dip in all of them is about 30° S.

Middle Creek.—It would appear that the upper large White-Ash coals lying above the upper main Egg-conglomerate—namely, the Donaldson "Ten-feet" and "Big" Coals, do not extend W. of the gorge of Middle Creek, or of the parallel of the Dripping Spring "Big Rock" in the Fisher's Basin, having been there washed out from this deeply-excavated portion of it. But on the E. side of the stream both of these coals, and one other, have been opened, dipping gently both N. and S. from the anticlinal axis.

1. The lowest or first of these is the little "Grey Vein." This is shafted on near the very centre of the trough.

2. The Donaldson Ten-feet Coal is here entered by a gangway near the synclinal axis, the dip being 19° N. At this spot the coal is soft and faulty in the gangway.

3. The Donaldson "Big Vein" or "Lomason" Coal has likewise been shafted on and identified. In this place this coal is not capped by the thin bed of coarse Egg-conglomerate, which is so distinguishing a feature of it at the Swatara, and in the Otto Tunnel (Morgan's).

At this pass of Middle Creek through the basin, the "Grey Vein," or the first above the "Big Rock," lies just at the level of the stream; the next, or Donaldson (Ten-feet) Coal, about 50 or 60 feet above it, and the upper or "Big Coal" 80 or 90 feet.

Swatara Creek.—At the fine natural section through the basin made by the valley of Swatara Creek, the same three coals above the upper Egg-conglomerate lie above the water-level, as already intimated. The two uppermost of these, the locally so-called Grey-Ash and Red-Ash coals, or the Donaldson Ten-feet and Big Vein, are there successfully mined. The lowest of the three, the Little Grey-Ash Vein, has been shafted on and "proved," but is not mined. It is 4 feet thick, and is good coal.

Though the N. dips from the Dripping Spring anticlinal, or South-bounding axis of this basin, are, at their steepest, even as much as 40°, the S. dips from the Swatara Falls anticlinal are at a much lower angle; and this general flatness of the measures, combined with the quite high elevation of the ground between the Swatara and Middle Creek, causes the two outcrops of even the highest of these coals—the Big Vein or Red-Ash coal—to recede quite far apart. Where they attain the watershed which separates these streams, they are probably from 1500 to 1800 feet asunder.

On the W. side of the Swatara, where the two upper coals now spoken of were mined by D. Brown & Co. (1852), the main and upper Grey-Ash bed (the Ten-feet Vein of Donaldson) basins about 80 feet above the water-level of the valley, and spreads its outcrops in this deeply-trenched hill-side, about 800 feet apart. This bed does not here saddle the axis S. of it, but, rising out in a N. dip, comes in again on the S. flank of that anticlinal, where it is known as McCreary's Grey-Ash Vein. Though called at Donaldson the Ten-feet Coal, such is really not its usual size, and in the locality now before us its true thickness is about 5 feet; but the coal is good. It yields on combustion a *grey ash.*

Black Valley Coal.—The upper or Red-Ash coal of this locality (Donaldson Big Vein and Forestville, or Black Valley Coal of more Eastern sections) lies at the Swatara, about 40 feet above the Grey-Ash coal, and of course fills a narrower basin. Its average thickness here is about 10 feet, and it yields of good coal some 7 feet. This coal affords a *pinkish* ash, or rather the upper bench or layer is pinkish, and the lower Red Ash. Neither of these beds had, in 1852, been extensively mined, their longest gangways being about 300 yards. Immediately over the Red-Ash bed there rests a rather remarkable roof-rock in the form of a coarse Egg-conglomerate, composed of the usual pebbles of quartz and white and grey sandstone. It varies in thickness from 10 to 6 feet, and is overlaid by the ordinary shale and coarse sandstone. It is an admirable guide to this coal, and though it does not retain its distinctive coarseness E. as far as Forestville, or W. to Middle Creek, yet it holds it as far as the Muddy Branch, and has there enabled me, in the Otto Tunnel (Morgan's), to recognise the coal-bed N. of it as the equivalent of this Red-Ash seam of Swatara, or the Big Coal of Donaldson. So coarse a mass of gravel strewed over the coal, and confined to so local a distribution Eastward and Westward, implies an unusual force and narrowness in the current which swept it in upon the surface of the broad marsh or peat-bog in which the coal-bed originated.

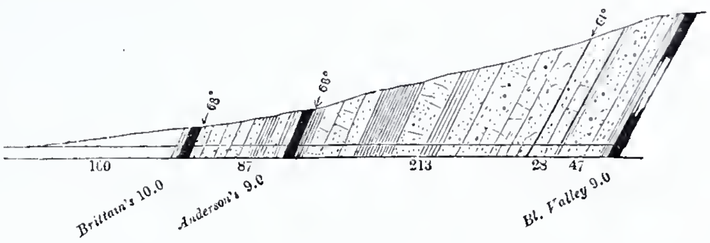


Fig. 173.—Morgan and Edward's Tunnel, Otto Tract, looking East.—1 *inch* = 200 *feet.*

WESTERN GROUP OF THE SUBORDINATE ANTICLINALS OF THE CENTRE OF THE COAL-FIELD, BETWEEN WEST BRANCH AND SWATARA.

Some of this group of subordinate anticlinals of the Peach Mountain belt, the most Western of this disturbed zone, range as far as the Swatara, between which and the valley of West Branch I shall now proceed to define and trace them in detail as far as their obscurity will allow. A few at least of these axes are probably not continuous throughout this length of country, but are disposed towards each other in a slightly oblique arrangement—such that, if prolonged in straight lines, they would pass each other, turning, in certain instances at least, into one another by a transverse warping and change of strike in the strata. Bearing in mind this feature, we may regard these chains of anticlinals, thus intimately linked, as truly continuous waves separating more or less continuous basins.

PEACH MOUNTAIN KANTNER AXIS, OR ANTICLINAL N.

The most Northern, and one of the best defined, as respects the district before us, of this belt of anticlinals, is that which I propose to name the Peach Mountain Kantner Axis.

This anticlinal, to which allusion has been already made as that forming the S. dips of the two Phœnix Slopes, though important in its influence on the strata in the district between Muddy Branch and Minersville, is, in its Western extension between West-West Branch and Muddy Branch, somewhat obscure. It has its maximum development between West-West Branch and Minersville. In the first of these localities it presents itself as a narrow and rather sharp axis, the summit of which is a short distance N. of the Northern Phœnix Slope. It passes through the Phœnix Tunnel, and in this neighbourhood lifts the coals into N. dips of about 50°, and S. ones of 35°. The road from Phœnix Mines over to Minersville follows very nearly parallel with this anticlinal. It passes through Minersville, crossing the valley of Wolf Creek about 500 feet S. of Heilner's Colliery on the Kantner Coal, and thence across towards West Branch through the spur or hill dividing these valleys, appearing on the road leading N. from Minersville, about a quarter of a mile above the main street of the village, at a depression, near which both its N. and S. dips are discernible. It crosses the flats of West Branch 1000 feet N. of the slope colliery of Wagner's Tunnel, and produces the S. dips of the strata near the tunnel's mouth. Further Eastward than this it is difficult so precisely to define its position; but in all probability it is the axis which, on West Norwegian, lies S. of the tunnel, entering at the so-called Green Park Vein.

Westward from West-West Branch it ranges to Muddy Branch, and thence to Swatara at M^cCreary's Mines. The most W. point to which it may be *continuously* traced from Minersville is on the crown of the ridge which contains the so-called South Mines of the Phœnix Company, where the very place of the axis is marked by the air-holes of the South-dipping vein of this mine. It pursues nearly the crest of this ridge to the head of the ravine which opens S. into Muddy Branch at Weaver's.

Adverting now to the lowest coals which lap over this anticlinal at the water-levels of the valleys which intersect it, we find that on the E. side of the West-West Branch it just lifts above the water-level the higher of the three small coals which lie between the Big Diamond and Cockle's Red-Ash seams. This last-named coal, worked below the water-level in the Phœnix New Slope, and above from the Phœnix Tunnel, has been followed in mining continuously over the anticlinal arch into its N. dips in Britton's Basin. (See West-West Branch Section.)

Further E., by the dipping of the axis (?), and the rise of the country to the watershed dividing the West-West Branch from Wolf Creek Valley, higher coals fold over the anticlinal, until near this watershed, on the Minersville Road, the two converging outcrops of the Peach Mountain Coal—that called the Kantner running to Heilner's Colliery, and that called the Peach Mountain traceable and mined into Minersville at the Catholic chapel—approach each other towards its summit to within about 150 feet of each other. The soft shales and argillaceous strata underlying this Peach Mountain Coal have permitted an extensive denudation on the back of this axis, from the watershed just mentioned, Westward into West-West Branch, and Eastward into the valley of Wolf Creek, the effect of which is to throw apart the two outcrops of this upper coal further and further in both directions.

MINERSVILLE CENTRAL AXIS, OR ANTICINAL O.

South of the Peach Mountain Kantner Axis, and in nearly strict parallelism with it, is another, which I have called the Minersville Central Axis, from its passing through that town. This cannot, in the present state of the developments, be traced with precision E. of the valley of West Branch, though it is very possible that one of the Peach Mountain anticlinal folds of West Norwegian may be identical with it. Either as a continuous anticlinal, or a chain of proximately connected short axes, this line of saddle is traceable nearly as far W. as the West-West Branch. For the district of West Branch it would seem to have its greatest elevation and closest compression in the vicinity of Minersville. In its range immediately N. of the Minersville or Lewis's Tunnel, it brings just to the water-level the coal-bed next beneath the Peach Mountain Vein; whereas on the West-West Branch it lifts to the day only the Peach Mountain Coal itself, here called the Fire Vein.

MINERSVILLE SOUTH OR PEACH MOUNTAIN INVERTING AXIS, OR ANTICLINAL O.

The anticlinal axis just Southward of the town of Minersville ranges across the West-West Branch, where it arches the Peach Mountain Vein above the water-level. The ground is naturally so obscure, and has been so imperfectly mined, that there is some doubt whether the West-West Branch axis is really this one or that previously described—namely, the axis O just N. of the mouth of the Old Tunnel. That the Southern axis is a flexure with inversion, is shown by the fact, that the two interior or Southern coals of the Old Minersville Tunnel, though dipping S., are identical with the two exterior ones, proving that a compressed synclinal ranges through the tunnel. A little further S. in the measures we meet only with uninverted N. and moderate S. dips. These last are exposed on the Minersville and Llewellyn Road.

The coals in the Old Minersville Tunnel (Lewis's) are the Peach Mountain and the vein next overlying it. Each of these, by the inverted fold, is twice produced, so that the tunnel seems to intersect four. In mining the Peach Mountain Vein westward from this tunnel, Mr George Spencer found the inversion of the S. side of the synclinal to continue for nearly half a mile, beyond which the coal became too faulty to be followed. In the same direction from the tunnel, the other or uninverted limb of the Peach Mountain Vein was found, after running parallel for several hundred yards, to recede to the Northward, its S. dip, which before was about 30°, growing flatter as the outcrop trended more and more to the N. of W. It is this curious feature, chiefly, which induces me to hesitate regarding the identity of the anticlinal N. of the tunnel, connected with these S. dips, with the anticlinal arching the Peach Mountain Vein on the West-West Branch; for such a swing Northward of the N. outcrop of this folded basin of the tunnel seems strongly to imply that the axis on its N. is sinking and expiring Westward.

This Peach Mountain short axis, or that N. of the Minersville Tunnel, takes in its course Westward a position in the S. slope, or high in the ridge, which also embraces the basin of the Phœnix South Coal; while the axis O of the hollow next S. of the West-West Branch south outcrop of Peach Mountain Coal, in ranging Westward, passes through the valley of the Southern part of Klauser's and Faust's farms, at the N. foot of the high wooded ridge which lies next N. of the turnpike road.

All the hill of the Kantner Coal has N. dips Northward to the white house in the woods (L. Garner's); the same N. dips are opened on the Wagner Tract.

Spencer's line, Eastward of Wolf Creek, extends 900 yards to the Delaware property. A new slope at Wolf Creek will command a fine field of gently South-dipping coal by the flattening of axis O, even to the N. dip of the Kantner Coal.

This anticlinal extends from a point W. of the West Norwegian nearly, if not entirely, to the Swatara. It constitutes the South-bounding flexure of the basin of the Peach Mountain Coal throughout this distance. Passing just S. of the town of Minersville, I have given it a designation derived from this well-defined position. On the West-West Branch the place of the axis, or centre of the arch, is in the ridge next S. of the South Phœnix Slope, and S. of the Peach Mountain Basin of the N. side of the same ridge.

At Weaver's, on Muddy Creek, an anticlinal, which I am disposed to regard as the same, passes between the dwelling-house and the Breaker of the Peach Mountain Coal. It is seen again at the bend in the road turning up the main Muddy Branch, and finally on the East Branch of Swatara, where the Spohn Vein, so called, of Muddy Branch, displays an anticlinal just at the water-level exposing its outcrop near the roadside. Beyond this point it has not been as yet detected.

Declining thus progressively from Minersville westward, this axis on the West-West Branch lifts out only the Peach Mountain bed; but this coal arches it at a height of nearly 100 feet above the valley, having been there mined over the anticlinal from the N. into the S. dip.

At the ravine at Weaver's the anticlinal exposes above the water-level a coal evidently one or two stages higher than the Peach Mountain Vein, which, immediately N. of this, is mined downward in a slope for 70 yards on a S. dip of 45°, proving certainly that coal to underlie this small surface-vein of the saddle.

It is probable, I have said, that the expiring anticlinal in the so-termed Spohn Vein, on the East Branch of Swatara, is a prolongation of this axis. This view will not be contravened by the interesting fact, that the Spohn Vein, so called, of McDonald's Branch Dale Colliery, worked Westward from the S. dip of another more S. axis, has been mined forward to this anticlinal point on the Small Swatara, even if it should hereafter appear, as I think it will, that the axis of the Branch Dale Slope expires W. of Muddy Branch before reaching the Swatara waters. As thus the South-dipping workings of the more Southern basin may be permitted to take their place on the S. flank of the main axis before us, if this axis really does extend itself even one mile Westward, it may contribute in a small degree to flatten the S. dips of the wide South-dipping belt of strata in its line of prolongation; that is, in the wide plateau which lies between the foot of the Thick Mountain and the Big Lick Mountain.

AXIS OF WEST-WEST BRANCH, OR ANTICLINAL P.

A fourth subordinate anticlinal crosses the valley of West-West Branch at a ravine which has been scooped out on the very back of the axis, about 850 feet S. of the final or S. dip of the Peach Mountain Coal. It would seem not to range far Eastward, certainly not to the valley of West Branch, nor has it been detected even as far as the Minersville and Llewellyn Road. Westward from West-West Branch it passes along the valley at the N. foot of the high wooded ridge lying N. of the Tremont Road, taking its course towards Muddy Branch through a range of open fields. On the E. side of the West-West Branch this anticlinal exhibits steep, almost perpendicular, N. dips, while its S. dips are about 35°.

It is not easy to decide at present precisely what coal it lifts nearest to the water-level on the West-West Branch, but it is very manifest that it does not bring up the Peach Mountain Vein. If this axis prolongs itself as far as the Muddy Branch, its course must take it just about to the neighbourhood of the sawmill pond S. of Weaver's, where the evidence of an anticlinal flexure is suspected.

GRISCOM'S AXIS, OR ANTICLINAL P.

About 1000 feet S. of the parallel of the short axis P, just described, there ranges another, distinctly traceable between West Branch and West-West Branch. From the absence of the axis P on the West Branch, there exists quite a wide belt of South-dipping measures between Minersville and the N. dips of the axis P. This latter is marked externally, on the E. side of West Branch, by a ravine or hollow in the hills, and on the W. side by a quite prominent knob. Thence it ranges Westward, crossing the Minersville and Llewellyn Road, and through the Griscom estate, where the very axis itself has been shafted on. Thence it runs forward to the West-West Branch, where, in the first railroad section above the town of Llewellyn, its nearly exhausted force is shown in a flattish undulation of the coal-shales with a N. dip of only 10° and a S. dip of 20°. This axis is evidently in greatest strength between the West Branch and Griscom's experimental slope upon it ; for throughout this part of its range the N. dips approach in most places to perpendicular ones.

It is possible that this anticlinal prolongs itself Westward of the West-West Branch, in which case it must pass through nearly the crest of the high ridge N. of the Tremont Road, and, if it appears on Muddy Branch, must meet this very near the old Spohn Mine. Almost in a line with this anticlinal we have the proofs of a flexure—possibly this one—more than 1 mile to the W. of its exhibition on West-West Branch, at Weaver's old Spohn Vein workings, on the W. side of Muddy Branch. Here an anticlinal—which, however, seems to droop Eastward, or rise toward the W.—just lifts the Muddy Branch Spohn Vein to a small height above the water-level, permitting both dips, which are but 50 feet apart, to be entered by one drift nearly under the arch. This axis, after rising to McDonald's Branch Dale Colliery, where it lifts and separates the same Spohn Vein into two somewhat remote outcrops, soon again subsides, and apparently disappears altogether, permitting the S. dip of the Spohn Vein, as once already stated, to swing its outcrop Northward, with a gentle dip and a greatly elongated breast, until it takes its station as the South-dipping vein of the next anticlinal north, or in the line of the general axis.

As there is at present no systematic mining along this anticlinal belt, or N. of it, connecting it with well-ascertained ground N. of Minersville, it is impossible to decide what particular coals they are which saddle the axis on the upland through the Griscom estate, or what beds it lifts above the water-level in the valley of West Branch. Most probably, however, the coals which it imperfectly develops are the small seams above the Peach Mountain Vein and below the Spohn. How far E. of the West Branch this anticlinal may extend, the obscurely-developed condition of the district does not permit us now to determine. Nevertheless, it is so nearly in a line with the course of the anticlinal I, visible on the W. side of the West Norwegian, N. of the old Spohn workings, or next S. of the Peach Mountain Basin, that I strongly incline to regard it as either the prolongation of this undulation, or as one of a chain of axes including both.

LLEWELLYN NORTH AXIS, OR ANTICLINAL QQ.

Another anticlinal, the sixth Southward of our present group, more faintly indicated than the last, from which it lies Southward about 1200 feet, crosses the West-West Branch just N. of the village of Llewellyn, and, ranging thence to the West Branch, is seen on this valley in the flat arch a little N. of the 7-mile post of the West Branch Railroad. It is evidently a feeble undulation, for its N. and S. dips are both at low angles as well on the West Branch as on the West-West Branch. This axis occurs in the range of the small Sandrock Coals of the Norwegian district, but what particular beds it lifts to the water-level at the only two valleys which intersect it, we have not the means of knowing.

BRANCH-DALE LEWIS VEIN AXIS, OR ANTICLINAL P WEST.

South of the Spohn axis of the Branchdale Colliery, about 700 feet, occurs the outcrop of the Muddy Branch (Weaver's) Lewis Vein. Low on the S. slope of the ridge, and just in this outcrop, the strata turn from a gentle S. to a N. dip, implying the presence here of another anticlinal. This seems to have no existence on the Muddy Branch, or Eastward of it, but from the point now spoken of Westward to the W. side of the main Swatara, it would appear to range as a continuous anticlinal. This axis seems to rise towards the W., for on the E. side of the E. tributary of the Swatara, a coal-seam, pretty evidently the same Lewis bed, is exposed above the water-level in separate North and South-dipping branches, which there outcrop 335 feet asunder, each of them perforated by a mine-drift. Moreover, the vein separates Westward of Branch Dale into two outcrops despite of the rising of the ground. On the W. side of the Swatara the position of this anticlinal is about 300 feet S. of the second railroad section N. of the Tremont Road, or just over the hill from Tobias's, but what coal it there lifts to the water-level, the poverty of exposures prevents our ascertaining.

This subordinate axis—the next anticlinal N. of that of the Big Lick Mountain—here exhibits N. dips as steep as 80° or 85°; and as these fill a belt of considerable width, we may infer that the flexure still retains some magnitude, and may range Westward even a mile or two before it altogether expires. In confirmation of this view, we may observe, in the broad flat elevated table-land which fills up the space between the South-dipping flank of Thick Mountain and the summit of Big Lick Mountain, the traces of a ridge holding its position all the way to the valley at Donaldson. Indeed, we can scarcely account for the wide expanse of high level ground in this space, but by assuming a lifting of the strata into a flat wide arch, or at least a flattening of the S. dips all along the plateau.

At the Branch Dale Colliery (McDonald's) the distance between the Lewis Coal saddle and the top of the Spohn Vein slope, in a N. and S. course, is 650 feet, and nearly in the middle of this space ranges the crest of the low synclinal ridge into which the Spohn Vein has its S. dip.

The thickness of this so-called Lewis Vein here is in all 9 feet, divided into three benches.

On the E. tributary of the Swatara the North-dipping part of this seam has a thickness of 6 feet.

LLEWELLYN MIDDLE AXIS, OR ANTICLINAL Q.

Between 700 and 800 feet S. of the Llewellyn axis F there occurs another still fainter and more obscure anticlinal, visible both at the town of Llewellyn and in the West Branch Valley. It is most conspicuous where it is intersected by the latter near the great bend of the West Branch stream, a few hundred feet S. of the railroad 7-mile post. Here it lifts above the water-level the same sandstones and other Coal-measures which are elevated by the anticlinal N. of it, and it exhibits, like it, very gentle dips both N. and S. of the axis. At Llewellyn, in the cut on the railroad near the N. edge of the village, this undulation, if indeed this be the same, is feebly expressed in a short flexure of the sandy olive-shales. (See this part of the West-West Branch Section.) Whether it ranges Eastward of the West Branch we cannot say, but we know that on the West Norwegian, in the belt of the upper Sandrock Coals, where this axis ought to range, if prolonged so far, there are no symptoms of its existence.

I have now exhausted the description of the group of subordinate anticlinals lying N. of the parallel of the Big Lick anticlinal, and S. of the Primrose Hill and Middle Creek anticlinal M, or that of Swatara Falls—so far, at least, as respects the complicated district enclosed between the valley of West Branch and that of the Swatara. I proceed next to an examination of the contents of the troughs or basins included among these axes.

AXIS OF BIG LICK MOUNTAIN, OR ANTICLINAL Q.

A regular and comparatively long anticlinal axis, its central portion well marked in the topography of the country, ranges nearly with the crest of the Big Lick Mountain of Donaldson, and its prolongations E. and W. It divides a regular basin at the S. base of the Thick Mountain from another equally well defined trough, which it encloses between itself and the Little Lick axis R. This Big Lick anticlinal has not as yet been definitely traced E. of the Swatara by any mining operations, or by external indications, nor do I think that it extends very far beyond it, for at that stream it is greatly reduced in force, and shows signs of soon subsiding. It crosses the Swatara Valley at a point a few hundred feet N. of the Pottsville and Tremont road, where the very arch of the anticlinal may be clearly seen in a cutting on the Swatara Railroad, about due E. of Tobias's Tavern. From this point it ranges W. in a very straight course through the ridge next N. of Tobias's, to which it imparts a more and more definite form and greater regularity of crest as it advances. It then crosses Middle Creek and Watering Run, where the North and South-dipping strata of the flexure are well exposed in several places in the cuttings of the Middle Creek Branch of the Mine Hill Railroad. Thence it ranges in the same line to where it crosses Good Spring Creek near Donaldson, beyond which, still ascending and dilating, it finally merges itself, between 2 and 3 miles W. of the notch of Good Spring Creek, into the N. flank of the Little Lick Mountain. The ridge which contains it, here becomes a mere shoulder or expansion N. of the Little Lick Mountain by the rising W. of the basin between them. The axis, however, maintains its place for several miles further along the N. side or brow of the South-bounding ridge of the Wiconisco Basin; an arching of the strata being still conspicuous in a deep ravine on the N. side of this mountain, nearly opposite Klinger's Gap, where a swell in the ridge denotes its presence. In all this distance, from the ravine of Watering Run next W. of the Main Swatara Creek, to the Good Spring Valley, if not further, the anticlinal has the form of a regular single arch, abruptly curved at its summit, with dips averaging 45° on its S. flank, and perpendicular ones on its N. At the Swatara, where the axis seems to be preparing to die away E., the N. dips are losing their high inclination, being scarcely more than 70°; and what is more significant of the exhaustion of the undulation in this direction, the belt of North-dipping strata is here very narrow, not more than some 70 feet wide between the actual saddle and the South-dipping measures of the basin N. of it. (See Swatara Section.) It is doubtful whether this flexure extends at all East of the E. tributary of the Swatara.

From what I have indicated of the elevation of this axis Westward, and its progressive declension to the Swatara, and the rising out of the basin between it and the Little Lick anticlinal, it must be apparent that, throughout several miles of its range E. from Klinger's Gap, it is saddled only by the coals of the White-Ash series. No mining developments thus far made give us the means of ascertaining where the Grey-Ash coals first take their place on the back of the anticlinal; but their W. limit over the axis is probably 2 or 3 miles W. of Donaldson. From all that can be ascertained of the coals of this anticlinal near Donaldson, it seems probable that the upper Grey-Ash seams lie under the water-level at the gap of Good Spring Creek, at the line of the axis, as much perhaps as 150 or 200 feet. The several coals which flank it in the Big Lick Mountain from this locality E., therefore, all appertain to the great Red-Ash series; and as these are five in number at the gap near Donaldson, and higher ones overlap the axis successively as it advances E., it is plain that the strata which it exposes on the Swatara belong to a very high position in the Coal-measures. From this fact we derive the further inference that the basins to the N. and S. of this anticlinal, and especially the latter, contain an extensive set of Red-Ash coals of the middle and upper groups of the series.

AXIS OF LITTLE LICK MOUNTAIN, OR ANTICLINAL R.

This prominent and interesting anticlinal, which, W. of Tremont, elevates the broad summit of the Little Lick Mountain, is, though of limited extension E., the great flexure of the W. end of the coal-field; for, by lifting to the surface the older formations beneath the Coal-measures, it separates the main basin of Pottsville into its two branches, the Dauphin and the Wiconisco basins. I have elsewhere identified it as the prolongation of the great anticlinal of the Half-Fall Mountain of the Juniata, and of the Path Valley of Franklin County. In the Little Lick Mountain, which is the high swelling portion of this anticlinal, rising and widening from Tremont W. to the oval margin of the deep red-shale valley, or "Kettle," as it is called, this anticlinal is a complex one, embracing, in reality, three parallel axes. The first and chief of these appears immediately at the N. edge of the village of Tremont, on the N. of the pointed spur descending there to the water-level, and is cut in Spangler's Tunnel. It ascends first along the crest of the main E. spur of the mountain, and thence pursuing its course obliquely W. in the same straight line along the S. brow of the mountain, runs through the middle of the high flats onward to the most concave part of the great "Kettle."

A very few hundred feet to the N. of this principal axis arises another, not traced as yet E. of Tremont, but showing itself first about half a mile W. of Tremont, on the N. slope of the mountain, where its structure has been developed in the mining operations of Spangler and Eckel.

A third and seemingly insignificant flexure occurs further W. up the mountain. Its position is between the two above described.

The main flexure of Tremont shows a dip of about 45° on its S. side, and a perpendicular one on its N. side. This steepness of the N. dip extends to beyond the point where the other prominent axis becomes fully overlapped, W. of which, along the now elevated ridge, the basin between the two axes exhibits N. dips of a less degree of steepness.

In like manner the second axis (that of Eckel's Mines) is a sharp flexure, with a perpendicular dip on its N. side for a considerable distance W. from its point of origin on the slope of the mountain.

Each of these waves gradually dilates and flattens in advancing W. They ascend in that direction at about the same rate; and the synclinal trough between them, marked nearly by the crest of the mountain as far as the passage of Rausch Creek, grows gradually shallower, and becomes at the same time wider by a slight divergence of the two axes.

How far the main axis prolongs itself E. from Tremont through the coal-field, it is impossible, in the present imperfectly-developed state of the belt which should contain it, definitely to determine. On the Swatara, about 1000 feet N. of the main anticlinal of the Red or Gate Ridge, we find indications, in the new cuttings of the Middle Creek Branch of the Mine Hill Railroad, of an anticlinal flexure; at least I so regard the steep-dipping rocks of the second cut of the railroad, for I am inclined to view them as overturned, and as implying, therefore, the existence of an axis with inversion not far S. of them. If there really exists an axis here, the question is, What is the probability of its being that of the Little Lick Mountain, prolonged thus far to the E.? It would seem to be nearly in the line of that flexure, though perhaps a little too far N. Let it be observed, that between Tremont and the Swatara we do not find any exposures of either N. or S. dips in the line where the axis should pass. As regards the probability of the identity of this axis of Swatara Creek with the Tremont flexure, I must suggest that some considerations are adverse to it. First, the space is a long one—as much as 3 miles; and as the Little Lick anticlinal is evidently declining rapidly at Tremont, we may fairly infer that it ceases altogether before reaching the Swatara. Again, N. of the West-running reach of Middle Creek in the ridge which the South-running course of the stream intersects, only S. dips are to be observed; and if the Little Lick axis were of much magnitude opposite to this hill, we might almost certainly look for N. dips at its S. base.

Of the coals exposed along this anticlinal axis, I would observe, that at Rausch Creek we find the main flexure presenting a beautiful wide arch or saddle, with gentle dips of the upper Egg-conglomerate and overlying strata, the conglomerate rising even on the E. side of the stream some 60 or 80 feet above the water-level. Across this arch of coarse conglomerate, the three lower White-Ash coals, which in this quarter underlie the so-called Big Vein, roll gently over in succession as we ascend from the valley E. along the axis to the level of the high flats; and a little higher up we discern the bench or terrace which denotes the crescent-like line of outcrop of the Big Vein itself, still considerably W. of the flats. It is obvious that, W. of Rausch Creek, this anticlinal, rising and spreading, becomes more and more denuded of the lower White-Ash coals which here still arch it, until at last, in the district beyond Kimmel's Tavern, at the fork of the turnpike, only the lower conglomerates, with the very lowest coal-beds, cover, in an almost horizontal position, the broad swelling summit.

Descending from the high flats E. along the axes of the Little Lick Mountain, the lower Red-Ash coal-seams saddle in succession in ascending order the double anticlinal of the mountain. Pursuing the subsiding crest towards Tremont, the middle Red-Ash coals come in, one after another, and when we reach the point of the spur at the water-level at Tremont, we are evidently on coals which are high in the Red-Ash series.

A more detailed account of those exposed by mining and shafting in the Little Lick Mountain will be presented in another place.

AXIS OF RED MOUNTAIN, OR GATE RIDGE ON ANTICLINAL S.

The W. portion of the great anticlinal now before us, or that included between the West-West Branch and its W. termination, opposite the Fishing Creek Gap in Sharp Mountain, is connected with a great feature in the topography of the coal-field. This well-marked and straight crest of the ridge called Red Mountain, subsides as a fold in the South-dipping strata of the N. barrier of the Dauphin Basin. The axis of the flexure crosses Lorberry Creek at the arch of the Big Coal, sometimes called the Rock Vein, where it lifts this large White-Ash seam to a position a little above an elevated water-level. It pursues thence the summit of the ridge, and appears on Rausch Creek as the first main ridge N. of the Sharp Mountain, the axis coinciding very nearly with the knob on the W. side of that valley. Here it is cut to a deeper level than at the valley of Lorberry Creek, and yet it does not bring to the water-level quite as high a part of the Coal-measures ; for the same Big White-Ash Coal, which is above the bed of that valley, lies under the bed of this at the arch or axis, a depth probably of from 50 to 100 feet. Between Rausch Creek and the Swatara at Tremont, the axis of the anticlinal occupies rather the S. brow of the rounded summit of the Red Mountain. The whole arch is beautifully exposed in the notch of the Swatara, where no less than ten coal-beds, all of them of the Red-Ash series, flank the axis between the N. and S. limits of the gap. (See Section of Red Mountain, Plate III.) The flexure at this exposure, and at Rausch Creek, is more compressed, or displays much steeper dips, both N. and S. ones, than on Lorberry Creek. Indeed, for the entire distance between Muddy Branch and Rausch Creek, the N. side of the arch is almost perpendicular, while the average plunge of the beds on the S. side is about 45°. At Lorberry Creek, Rausch Creek, and the Swatara at Tremont, it is a regular and single anticlinal flexure of the normal form ; but between the gap of the last-named stream and that of the East Branch of the Swatara, it loses this simplicity by the introduction of one or more subordinate undulations which attend the main axis, thence the whole way Eastward to the vicinity of the West Norwegian.

This change in its structure the reader will readily discern, by inspecting those portions of the Western series of sections which depict the Red Mountain rocks, and comparing those W. of the East Branch of Swatara with those E. of it.

At the natural section where this stream passes through the anticlinal ridge, the Swatara Railroad exposes in its cuttings the exact features of the central parts of the anticlinal, enabling us to note two closely-connected flexures, distant from each other only about 350 feet.

The more Northern of these is a compressed or folded axis inverting the strata just N. of it a little past the perpendicular, and lifting those immediately S. of the bend to a steepness almost as great. Though it appears to be a subordinate contortion in a synclinal trough of sandstones and shales lying between the more regular axis S. of it, and the succession of S. dips N. of it, I am disposed to regard it as the compressed termination of the anticlinal of the Little Lick Mountain, or axis R. Occurring in the midst of synclinal dips, it repeats at the level of the railroad a bed of coal, and the shales embracing it, four times within their narrow basin. (See Section on Swatara Railroad, near Middle Creek Railroad Junction, Plate III.)

The Southern flexure adjoining this contortion is just at the axis a flattish arch elevating somewhat lower strata than those involved in the contortion above referred to. This is perhaps the true axis S, or that of the Red Mountain. But a question here arises, whether the present, or any other of our longer anticlinals, possesses that undisturbed symmetry and regularity which are implied in the notion of the continuous prolongation of one simple axis-line? Certain it is that different anticlinal belts differ in a marked manner in the degree of complexity or simplicity presented by them near the summit of the wave, and this of the Red Mountain, or Gate Ridge, is an instance of this difference even in the several portions of its own long line. It is simple from its W. origin Eastward to beyond Tremont; complex from that meridian onward nearly to Pottsville; simple again, with slight inversion, from the Norwegian to Belmont; and again contorted or undulated from that quarter forward to where it smooths itself into a flatter and more symmetrical wave between the parallels of the Five-mile Board and Middleport, preparatory to merging itself into the Sharp Mountain.

N. of the irregular flexure in the centre of the Red Mountain anticlinal at the gap of the East Branch of Swatara, there occur a series of steeply South-dipping strata, distant from the axis rather more than 1000 feet. They bear indications of being overturned, and the idea of their inversion is strengthened by their having the unusual dip of 70° S., and lying N. of other beds dipping with the normal amount of pitch of 40° to the same quarter. If these rocks, which are exposed in a vacant cutting of the Middle Creek Railroad, are really overturned, there is undoubtedly one important anticlinal ranging at the N. base of the Red Mountain, at a distance of some 700 or 800 feet N. of its proper central axis. This implied anticlinal R is the one to which I have before alluded as being nearly in the line of prolongation of the main Little Lick axis, but a reconsideration of the evidence induces me to regard it as lying too far N. If that axis extends thus far towards the E.—and there are reasons for supposing it does not—its more probable prolongation is the steep flexure R.

The next point E. at which the Red Mountain axis is distinctly exposed, is on the lower Muddy Branch at Bettinger's Southern Mines on the Dundas Lands. Here the flexure is apparently single, but it shows its usual degree of compression, for the dips on the N. side of the axis are perpendicular, and those on the S. side amount to 40° S.

It is worthy of note, that at the pass of the Muddy Branch, N. of this point by several hundred feet, we recognise another anticlinal, agreeing in its relative position to the axis of the ridge very nearly with the place of the assumed axis R, on East Branch of Swatara, N. of the prolongation of the Little Lick anticlinal. This is near the sawmill on the Muddy Branch at Bettinger's North Mine. That there is an important axis here, along the N. side or slope of the Red Mountain or Gate Ridge, is obvious from the dips visible on the railroad, a regular S. pitch of 30° up to 45° meeting abruptly high angles of 80° and more, with all the appearance of inversion in the strata. We may moreover observe, S. of this indicated synclinal or basin, a long narrow longitudinal valley corresponding in range with the Little Lick line of anticlinals; and this is, in all probability, the position of a sharp bold axis overturning the strata on its N. side into this high dip of 80° S.

On the West-West Branch below Llewellyn, we again meet with the main anticlinal of the Gate Ridge or Red Mountain. It is indicated near the Salem Colliery in the passage from true S. dips into the overturned ones of the so-called Gate and South Gate Veins of this locality.

South of the main axis there is a more trivial undulation affecting the outcropping portion of the so-called Salem Vein, but whether this is an axis of any length, or only a mere local roll, the mining explorations of the district do not show. My impression is that it has but a limited extent. (See West-West Branch Section near Silverton.)

About 1300 or 1400 feet N. of the inverting or folded flexure of the Gate Veins there are indications, in a series of Sharp S. dips lying next S. of the more gentle ones at the town of Llewellyn, of the presence of another axis, also with inversion; but it must be admitted that the evidence of this fold is obscure. It will be noticed that the place assigned to it relates it to that which we have seen existing N. of the chief one both on Muddy Branch and on Swatara.

CHAPTER IX.

COLLIERIES BETWEEN THE WEST NORWEGIAN AND THE SWATARA.

Having in the preceding chapter traced, with all the precision at present practicable, the course of the numerous anticlinal flexures, great and small, which range from the West Norwegian Valley to that of the Swatara, and pointed out the principal coal-seams which saddle them, I shall, in order to complete our view of this part of the coal-field, offer here a series of notes upon some of the more instructive collieries. These notes were taken in 1853, and therefore are not in all their particulars applicable to the present day; yet as many of the data given in them are of a permanent nature, and of importance as a key to the position of large stores of coal under the water-levels of the country, they are retained without alteration. If the time yet to elapse before the issuing of the work permits, the existing condition of these and many other collieries will be noted in an Appendix. As in the preceding chapters, the localities will be treated in regular order from N. to S., and along each belt from E. to W.

MINE HILL GAP COLLIERY (JOHN DOHERTY'S).

Coals—1*st Bed.*—The Mammoth seam, on the W. side, is from 12 to 13 feet thick, with 9 feet of coal: it has three genuine benches; the lower has from 3½ to 4 feet of clear strong coal and 3 inches of slate; the middle bench has 18 inches of regular coal, and from 3 to 4 feet of Bone coal and slate-parting; and the upper bench is 2½ feet thick. The dip is about 30°. The roof is sandstone, becoming slate towards the E. It is separated from the next overlying coal, 140 yards from the gap, by only 4 feet of slate: this interval augments on going W. On the E. side of the creek, the two are parted by a thin seam of slate.

The 2d Coal is the Black Heath bed, 4 feet thick, with 3 feet of coal: above this are 10 feet of slate, with two thin coal-seams, one 12 inches, the other 6 inches thick.

The 3d Vein.—The Black Valley Coal is 10 feet thick, and has 9 feet of good coal. It has been mined above water-level from the W. side of the stream almost to Wolf Creek.

DUNDAS COLLIERY, No. I. (ABOUT 400 YARDS WEST OF DOHERTY'S).

The *Slope* on the Black Valley Coal dips 35° S. The average thickness of the bed is 9 feet, with two benches and no parting-slate. It has a hard slate on the top of the coal, and sometimes a quite thick one; at other places there is none. About 28 yards N. of the slope is what may be the Black Heath Coal, or it and the Big Coal together: the thickness is 14 feet.

A tunnel enters the hill S. of the Slope Coal, and cuts the Silver Coal 21 yards in, and at the end of the tunnel occurs the Black Valley (Slope Coal). This tunnel is 110 yards long. The gangways extend E. three-quarters of a mile, and W. to the gap about 700 yards.

MINERSVILLE.—BASIN *O o.*

Wagner's Tunnel cuts a basin with two coals on each dip. Spencer is now (1852) sinking a slope Southward on Coal No. 2 of the tunnel. The basin of Coals No. 3 and 4 in this tunnel is apparently the basin next N. of the mouth of the Minersville Tunnel.

Nos. 3 and 4 Coals basin out and rise to the E. within 700 yards.

Minersville (*Lewis's*) *Tunnel.*—Cuts four coals forming a folded synclinal, the axis dipping Southward: there is an anticlinal just at the tunnel's mouth. The first coal cut is 8 feet thick: the last measures from 8 to 9 feet—is supposed to be the Peach Mountain Coal. The middle coals, 4 and 3½ feet, basin together. The tunnel is 80 yards long. The main gangway was driven on the Back Coal. It was driven 280 yards E. (?) and then the strata became confused.

WEST BRANCH.

The anticlinal F, West of Mount Laffee (West Norwegian), which at West Branch arches the Oak Hill Coal and its overlying coarse conglomerate, is traceable with the similar flexure of the Oak Hill Colliery on Wolf Creek, where the same overlying conglomerate arches beautifully over the coal, just above the water-level, on the E. side of the valley. Here it has gentle S. dips and steep N. ones. It is traceable thence Westward through the hollow of the Western Branch of Wolf Creek, and into the high table-land which connects the Primrose Hill with the flank of Mine Hill; and finally, in the vicinity of Woodside, it loses itself high on the slope of Mine Hill, where its vestiges are perceived in certain irregularities and flattenings in the S. dips of the Black Valley Coal, and the other lower beds of that range.

There are two coals close under the coarse Nut and Pea-conglomerate which saddles this Northern axis. These are, in all probability, the two Norwegian Orchard Coals. The higher is within a few yards of the overlying conglomerate, and the lower is in some places 5 feet beneath the upper. This lower coal is in some places 10 feet thick, the upper 5 feet. By a careful examination of the measures on Oak Hill and at Mount Laffee, the Oak Hill coals were decided to be the Orchard beds of West Norwegian. Between the conglomerate covering the Oak Hill or Orchard coals of West Branch, and the conglomerate rock of the Big Diamond Coal, are three small coals on West Branch. The highest of these is the Bast Big Diamond Coal of Wolf Creek: the other two inferior ones are not named here, but are seen also on West Norwegian.

Coals on the S. Side of Mine Hill Gap—Basin C E West:—

a. There are two bony coals over the great conglomerate, separated by a rib of rather coarse Nut-conglomerate. Each coal is about 4 feet thick.

(It has been supposed that the Jugular Coal underlies the Big conglomerate, and is under the arch of Mine Hill.)

b. The Skidmore Coal is separated from the upper bony coal by coarse-grained dark-grey sandstone, and Pea-conglomerate. It has not been opened here.

c. A small coal lies about 20 yards above the Skidmore Coal; the interval is composed of slate and shale. The coal is about 3 feet thick.

d. We then have the Mine Hill Coals, or Mount Laffee Mammoth seam, consisting, at Mount Laffee, of two beds, the lower 21 feet, and the upper 12 feet thick, separated by about 30 feet, but this space is very variable. At Western Mount Laffee Colliery the separating mass of slate is only 2 feet thick. The top coal is here about 13 feet thick, the under one about 20 feet. The upper bench is supposed to be the Black Heath bed.

The Diamond Coal of West Branch is identified with the Diamond Coal of Wolf Creek, by an overlying coarse Nut-conglomerate. The *Cockle* Coal has a Pea-conglomerate above it. Most probably this Cockle bed is the S. Diamond of Silver and Mill creeks. The Lower Orchard of West Branch has a remarkably black fissile slate over it. The basin of the Oak Hill coal dies out Eastward, and the dips become S.

Fogerty's Colliery, W. of Westwood.—The slope is down on the *Black Mine* Coal about 235 yards: the dip at the top is 38° S.; at the bottom it is much steeper: the average thickness of the coal is 7 feet in three benches, with little or no partings. The coal is good; there are three lifts, and gangways on each lift, which run E. and W., and are nearly straight; the middle gangway is worked W. about 830 yards. The roof and floor of the bed are regular. From the bottom of the first lift a tunnel is driving Southward to the Tunnel Coal. At the bottom of the second lift, another tunnel is already driven from 55 to 60 yards, also to the Tunnel Coal. From the tip of the slope, the bearing to Pott's Slope, on the Black Mine Coal, is N. 70° E.

SECTION OF THE COAL-MEASURES IN SHARP MOUNTAIN AT THE WEST BRANCH GAP.

The strata being somewhat inverted or dipping S. 80°, the actually ascending order is apparently a descending one, but we shall commence as usual with the originally lowest beds.

1st Coal—Twin Vein.—The lowest coal discovered in the Sharp Mountain at this gap is the Double or Twin Seam; also at the base of the series at Mount Carbon and elsewhere. It consists of—coal 2 feet, slate 9 feet, and coal 3 feet.

Between the Twin Coal and the next overlying bed, there intervenes a body of conglomerate and sandstone about 150 feet thick.

2d Coal—Plumbago Bed.—The second seam or Plumbago bed at Pottsville, measures at the West Branch from 8 to 10 feet, though, being overturned and crushed, it is highly probable that such are not its true dimensions.

Overlying the Plumbago seam is a mass of sandstone, about 140 feet thick.

3d Coal, or Barcleugh Vein.—This seam here measures about 6 feet, but its true size is probably greater. Between it and the next coal the strata are sandstone and slate, filling a space of about 90 feet.

4th Coal, or Knickerbocker Vein.—This coal, as proved in a drift at the West Branch, showed a thickness of 6 feet.

Overlying the Knickerbocker bed we again meet with sandstone and slate, filling an interval of about 60 feet to the next coal-seam.

5th Coal, or Three-Feet Vein.—This bed measured at the point at which it was opened by a drift, about 3 feet, as its name implies.

From the thin bed just mentioned to the next or Furnace Vein, the perpendicular distance through the strata is about 300 feet, the measures consisting of sandstone and slate.

6th Coal—Furnace Vein.—This bed displayed a thickness at the spot where it has been mined, of from 4 to 6 feet, the coal being, in the main, good and sound.

Above the furnace-bed occur sandstone and slate through a thickness of 120 feet to the next coal-seam.

7th Coal.—This is a small bed, apparently only 2 feet thick. It is the uppermost of the series of coals clearly opened in the Sharp Mountain at this locality.

The above measurements are on the authority of Mr Bennett. Our own earlier measurements, made when the strata were less distinctly developed, are somewhat different.

COLLIERIES—WOLF CREEK.

Slope on the Bast White-Ash Coal (*the Primrose*).—This slope was sunk 120 yards in 1853; the dip was not regular, being flatter at the top than at the bottom. The thickness of the coal is irregular, being from 6 to 12 feet in thickness in two benches. The gangways run E. and W. into faults in both directions. There is very little top slate: the Slope Coal had not been worked for three years. From the bottom of the slope the strata were tunneled N. nearly 100 yards. At 50 yards the tunnel cut the Black Valley Coal, and at its end it cut the Black Heath Coal. The Black Valley Coal has from 7 to 8 feet of coal and dirt: it was worked E. to the line, and Westward it ran into a fault.

The Black Heath Coal has 4 feet coal, with irregular dip: it has three benches, with no partings: the gangways run E. and W. several hundred yards. In tunneling 40 yards further N. they cut the Seven-feet Coal, which was not good here; but at Serril's Mine further W. it was good on the top lift.

Bast and Pearson's Slope on the Bast White-Ash Coal.—This slope was down 169 yards. The coal is 8 feet thick in two benches, with no partings; the top and bottom are regular: it has three gangways; one, at a depth of 85 yards, runs W. 700 yards. The slope does not start on the Bast White-Ash coal. It runs 85 yards down in a small 3-feet bed S. of the White-Ash coal; from thence a tunnel was driven 20 yards N. to the White-Ash bed, and there a counter-gangway was started. The slope then continues through slates, and cuts the White-Ash coal as in the diagram. At the bottom of the slope the gangways run E. 92 yards, and W. 170 yards, at the end of which there is a tunnel driven N. 90 yards.

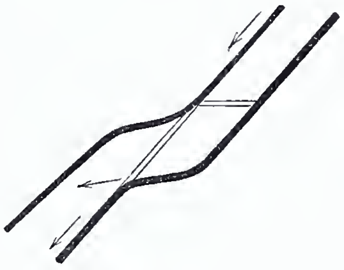


FIG. 174.—Bast and Pearson's Slope.

Serril's Lower Tunnel.—This runs Northward 265 feet to a coal (the Black Valley). A gangway extended W. on this nearly 500 yards, where the tunnel was driven Northward 62 feet to the Black Heath coal, and still further to the Skidmore (?) coal.

Serril's Upper Tunnel.—The accessible thick White-Ash coal-beds at the foot of Mine Hill are entered by Serril's Upper Tunnel. They are the Back or Skidmore, the Black Heath, and the Black Valley beds, and have the dimensions and distances apart shown in the accompanying cut.

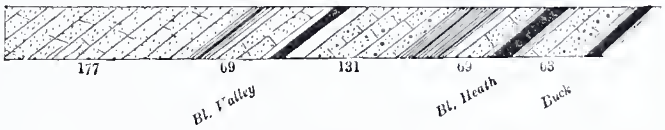


FIG. 175.—Serril's Upper Tunnel, Wolf Creek, looking E.
1 *inch* = 200 *feet.*

Holman and Company's Slope.—The slope on the *Oak Hill* Coal is down 80 yards to a basin, then 30 yards on the N. dip to a saddle. The coal averages from 8 to 10 feet in thickness, frequently even 14 feet. The N. dip is thickest; it is in two benches; the top is 7 feet thick, with bony coal between. On the top of the coal lie 14 inches of slate, then sandstone, &c. From the bottom of the slope the gangway runs E. and W. Eastward, the gangway turns its course to the N. base of the saddle of conglomerate at the Breaker. The distance of the turn Eastward from the slope is 150 feet. It is all worked off by water-level drifts.

Bast and Pearson's Slope on Red-Ash Coal.—The coal-bed of this mine is the so-called Big Diamond, 5½ feet thick in two benches. The top rock is of slate and bony coal; the bottom is of slate and hard rock; the dip is from 42° to 45°, and regular; the slope is 150 yards down; the gangways run 1400 yards E. and 1700 W. They are now (1852) tunneling N. to the two small beds: behind them they expect to cut the 3-feet coal at 90 yards, and the next 10 yards further W. The gangway ran into a fault towards its end: it has been driven 200 yards on the fault.

Kear's Slope on the Oak Hill Grey-Ash Coal (*Lower Orchard Bed*).—This slope is down 200 yards.

Jeanes and Spencer's Slope on the Peach Mountain Coal.—This mine is down 120 yards, with S. dip: in one lift the dip is 35°. The coal is 8 feet thick in four benches; in the first bench it is 3 feet thick, and in the second and third 9 inches, and in the top bench it is 4 feet thick, with a little slate between them.

From the bottom of the slope a tunnel was driven 220 feet N. to the Platt coal, 3½ feet thick: the gangways run E. and W.; the W. gangway runs into a dirt-fault at 600 yards. The distance between the Platt and Spencer coals at water-level is 325 feet. From Spencer's Slope to a small coal S. is 816 feet. The distance across the strike, between the Spencer and Little Diamond coals, is 550 feet.

From the outcrop of the Spencer Coal at water-level across the strike to the Kantner Coal is 1160 feet.

Little Diamond Coal Slope.—In this slope the dip is from 30° to 40° S. The course of the Little Diamond water-level gangway is about S. 80° W.

The Kantner Coal has been worked E. through to West Branch: the coal there rolls over in the hill even to a S. dip.

Heilner's Kantner Drift has a very steep N. dip; it was worked W. and round the point of a basin into the S. dips of Spencer's Slope coal.

ANTICLINAL FLEXURES AND THEIR COALS ON WEST-WEST BRANCH.

Griscom's Axis and Mines.—The anticlinal flexure of *Griscom's Land*, axis P, after passing through the disturbed measures in the railroad-cut N. of Llewellyn, takes the hill or ridge which lies next N. of the turnpike road, and thus ranges on to Muddy Branch. The same hill may embrace the small axis just N. of Llewellyn, if indeed it extends so far Westward. It would seem to be very nearly in the prolongation of that of the Big Lick Mountain. I am disposed to regard the anticlinal next N. of Llewellyn as belonging rather to a chain of lesser axes than to one continuous one. Griscom's axis seems to pass the Muddy Branch near the outcrop of the Lewis Coal (or possibly it is that further North), and ranges thence Westward to the Swatara, where it is the second axis N. of the turnpike. This last named we have traced for about half a mile further

Westward along the crest of the hill, but we could not discern any proof of it on or near the Donaldson Road at the E. tributary of Middle Creek, from whence I infer that it there expires.

Griscom's axis seems to dip at the pump-slope Westward, and brings together there the North and South-dipping parts of the coal, for it has not been found in shafting Westward of that point. This axis crosses the Minersville Road, about 400 yards E. of Frain's house, at a ridge on the road where the two outcrops of the Slope Coal are from 100 to 150 feet asunder. The North-dipping part is vertical all the way, the South-dipping somewhat flattish. The strike of both is regular from a point 100 yards E. of the pump-slope, but at the pump-slope the North-dipping part of the coal trends N. 55° E., and the South-dipping trends due E.

This axis, traced Westward a quarter of a mile, leads us to a ravine in which is a slope on a South-dipping vein nearly 100 yards to the S. of the saddle. This new slope has been sunk in the coal 45 yards. Near the outcrop it is 6 feet thick, then it jumps two or three times downwards and upwards, and at the foot of the slope is only 4 feet thick, soft, and not workable ; dip due S., and strike E. and W. ; average dip from 40° to 50°. This axis prolongs itself Westward, and passes the West-West Branch near the swamp at the Railroad Bridge. It seems to be the anticlinal of the hollow South of the South Peach Mountain outcrop. A hard coarse sandstone rises in the axis on the crown of the ridge, and is seen on the Minersville Road : thence it runs to the N. of Weaver's.

Red Mountain Axis.—On the West-West Branch below Llewellyn we find this axis indicated in the dips at the Salem Colliery, worked in 1852 by Heilner & Co. Here we have proofs of a small anticlinal and synclinal flexure on the S., in the position of the outcrop of the Salem Coal, and a chief or principal fold in the strata a few hundred yards to the N. of this, in a longitudinal or E. and W. ravine dividing two ridges, in the S. of which is the Tunnel Coal, and in the N. the Gate Coal. This main axis seems to be a folded one, for the steep dip of the Gate Coal, which is as much as 65° or 70°, succeeding immediately the gentler dips of the Tunnel Coal (45°), implies strongly the presence of an inversion on the N. side. It is possible that the *Little Lick* axis prolongs itself as far as the West-West Branch, for at about its usual position N. of the main anticlinal we have steep dips of 62°, and in the first exposures S. of Llewellyn, as if the strata of this belt were likewise overturned. Possibly they belong to the inverted rocks which include the Gate Coal, but the distance between them is greater than is generally occupied by the breadth of a perpendicular or inverted set of strata in this region of closely-approximated anticlinals.

The Little Diamond Coal (of Wolf Creek, or Big Tracey of Norwegian) barely reaches the water-level in the basin included between the broad arch of Primrose Hill on the E. side of West-West Branch and the saddle from 600 to 700 feet N. of it ; but in the small basin north of this N. axis it does not descend to the level of Patten's Valley. (See Section on West-West Branch.) The Red-Ash Cockle's Coal descends to below water-level in Patten's Valley, and soon rises again in a flat basin ; then arches over the small N. axis, and again basins under the little trough of the Little Diamond Coal, to reascend as Britton's Coal, the equivalent of the Phœnix Upper Slope Coal, worked by Miller on the next S. dip.

Considering the Phœnix Upper Slope Coal, or Little Diamond of West-West Branch, as the Big Tracey Coal, which it unquestionably is, the small coal next beneath it is the equivalent of the Yard Coal of Mill Creek, and the 4-feet-thick seam under this again is the Peacock Coal of the same district. By this tracing we learn that, while the capping-rock of the Little Tracey Coal has in reaching West-West Branch grown less pebbly and massive than at Mill Creek, the subjacent hard stratum which underlies the Big Tracey Coal, and that above the Peacock (Cockle's Red Ash), have both of them become considerably coarser and more conglomeritic. The uppermost of these, in its higher layers, is in fact a true Pea and Nut-conglomerate. It is readily recognised by the well-smoothed and ovoid form of its pebbles, and the sparse manner in which those are disposed through the sandstone material of the rock, making it a true plum-pudding stone.

In the very centre of the wide gentle arch of the Primrose anticlinal, on the E. side of West-West Branch Valley, we find, at 20 or 30 feet above the bed of the valley, the well-marked conglomerate which caps the so-called Big Diamond of Wolf Creek. The coal lifted above water-level on the W. side of West-West Branch Valley, and there mined in Miller's North and South Mines, is here on the S. side scarcely elevated above the flats of the valley, showing quite a marked subsidence Eastward of the whole saddle.

MILLER AND STAHL'S PHŒNIX COLLIERY.

The drift is on the North Vein, and the dip N. is steep at the entrance of the drift, but as the gangway extends W. the dip becomes much *less*. It was driven W. about one mile. This N. bed is in the round-backed hill directly S. of the first anticlinal S. of Forestville, or axis M. The North Vein is 7 feet thick, with a 2-feet coal 2 or 3 yards above it. S. of this hill is a valley, and in the hill next S. is worked what is called the South Vein, which here basins, so that the gangway runs for a part of the way just along the bottom of the trough. This coal is regarded by some persons as the same with the North Vein. It, like the latter, is about 7 feet thick, with a 2-feet vein a short distance above it.

A few hundred feet S. of the Company's Store is an old drift on what is called the Peach Mountain Coal. This is merely the continuation of the Peach Mountain Basin prolonged from Minersville.

The anticlinal axis occupies the hollow between the round-backed hill, and the next one on its S. On the opposite or E. side of the valley, the axis just mentioned seems to be much feebler, serving only to give a gentle undulation ; but this requires careful examination. There is here apparently a long low flat arch of conglomeritic sandstone.

As we proceed Northward, approaching Britton's Colliery, we have S. dips, and farther still a decided anticlinal. This is admirably exposed at a higher level on the hill-side along the railroad leading to Britton's Drift. Here we have somewhat massive and flaggy sandstone, with conglomerate displaying a gentle S. dip, becoming then flat, and afterwards turning into a somewhat steep N. dip of say 45°. The direction of this anticlinal would carry it along the N. base of the round-backed hill above referred to, which is well marked on the Map. The coal worked by Britton lies above this sandstone, and is said to be the same as the North Vein on the other side of the creek. It is undoubtedly *inferior* to the Peach Mountain. Mr Berryman says he worked up the North Vein over the saddle into the South Vein ; the three dips are therefore *certain*.

LLEWELLYN.

The hill or ridge S. of the Pottsville and Tremont Road, and S.E. of Llewellyn, contains three coals. The lower coal, with dip 60° S., is 6 feet thick, slaty, and is the same which shows soft coal and dirt 12 feet thick W. of West-West Branch: the second is a thin coal, 3 feet thick: the third is a large bed of coal, 8 feet thick, soft and shelly; it dips from 20° to 25° S. and its outcrop is a short distance N. of the Northern brow of the ridge. This ridge extends across West-West Branch to that of Klauser's fields.

The main Gate Ridge is far to the S. of it. It appears to be a monoclinal ridge; its crest is formed of a coarse sandstone, dipping rather steeply S. It coalesces Eastward with the ridge next S. of it on the N. and S. trend of the turnpike; they also unite W. of the Muddy Branch in a high ridge. The true Red Mountain or Gate Ridge is still S. of this high one, and is split by a longitudinal hollow Westward of Heilner's Salem mines, caused by the denudation on the anticlinal.

SALEM COLLIERY, BELOW LLEWELLYN.

The veins worked in 1853 were only—

The *Salem Vein*, which had a slope on it, 150 yards down, on dip 45°.

The gangways were driven E. 250 yards, and W. 1400 yards. The only vein worked had 3½ feet of coal; the benches here are not regular. The top is generally 3½ feet thick; there is often a bottom bench of 1 foot in depth, underlaid by a sandstone, as at Port Carbon. They expect to take 20,000 tons this year from the Salem bed.

The *Faust* Coal had not been worked; it was found not to be good in the drift. The Salem Coal had been shafted extensively on the Swatara, but is faulty. A tunnel running Northward 70 yards from the Salem bed was intended to cut the Faust Coal; the vein there was about 4 feet thick, but very faulty.

The Faust Coal had not been opened at Swatara. It has a N. dip of 55°, and seems to be the Salem; it *does not crop out on the mountain.* There are 36 yards of cap rock.

The *Rabbit Hole* Coal has here 3 feet of coal; it had not been worked here, or anywhere to the Westward. This is certainly the Salem, on its final rise to the outcrop which is shafted on the hill.

The *Tunnel* Coal is here about 6 feet thick; the bottom layer 1 foot of soft mining, and a 5-feet top bed of good coal. It has been worked 1400 yards Westward, and not here to the Eastward, as it has been at Crescentville; it is generally in good condition on West-West Branch.

The *Black Mine* Coal has here a thickness of about 5 feet of coal; its benches are very much the same as those of the Tunnel Vein. It had not been worked hence Westward; but twelve or thirteen years ago it was mined some 500 yards Eastward by Samuel Heilner. The gangway ended in a rock-fault.

The *Selkirk* or *Lawton* Coal was not mined here at all: it was shafted on, and proved too poor to work.

The *Gate* Coal was here mined to the Westward 500 yards to the line of this Estate, and driven Eastward from Little Muddy Branch. Another seam was worked from 500 to 600 yards, to meet the line. It has therefore been worked above water-level through to Little Muddy Branch. It has $4\frac{1}{2}$ feet of coal, all in one bench; has $3\frac{1}{2}$-feet clod on the top of it. This upper layer, or "clod," is a soft slate at Muddy Branch. The dip here at West-West Branch is 65°, but becomes 40° one mile to the W.; and the clod is there gone, so that, the roof being good, the coal is easily worked. This clod is a rotten slippery slate, and will sometimes run like sand, making the coal difficult to mine. It would seem not to be a true shale; the fact stated that in the same gangway the vein flattens to 40°, and has a good slate roof, looking much as if the coal is not an overturned bed at all.

The *Little Gate* Coal was not even found here. The shafts on the ridge are certainly not on it.

The *South Salem* Coal has been worked W. 200 yards, but was soft and faulty, and not worth mining; its thickness was 4 feet.

A tunnel goes from the Salem Coal, at a point 700 feet W. of the foot of the Slope, Northward towards the Faust. It had been driven 70 yards, and at a depth of 35 yards it turns over into a N. dip about 50°: the remaining 35 yards is all through N. dip. The measures are chiefly sandstone, with a little slate. The tunnel was expected to cut the Faust Coal at a depth of 65 or 70 yards, but the North-dipping strata have disappointed all calculations.

The actual axis near the Gate Coal has not been detected, and it is even doubtful if the Gates are not here true South-dipping coals. Perhaps the axis lies between the two ridges of Red Mountain.

BRANCH DALE COLLIERY (McDONALD'S), MUDDY BRANCH.

At the tip of the new slope on the *Lewis* Coal there is a saddle which has been traced to Swatara. The distance from the Lewis Coal saddle to the Spohn Coal Slope, on the S. dip, is 664 feet, on a N. and S. course. The axis of the Lewis Coal rises Westward. The coal saddles it, in some places, on higher ground, and at Swatara the beds are 335 feet apart. The Lewis Coal Slope descends into a water-level drift; the dip is from 30° to 32°. The coal is 9 feet thick, and when regular, is in three benches; the top one is from 4 to 5 feet thick, with 1 foot of Bone Coal.

The *Spohn* Coal is in all 6 feet thick; it has a bottom bench from 15 to 18 inches thick, and bone 18 inches; the top bench is from 3 to $3\frac{1}{2}$ feet of good coal: it was in fault for 800 yards, from the introduction of a sandstone in the position of its top bench. It runs from the slope 300 yards E., and 500 yards W. The Spohn Coal has a rock top, with 3 feet of slate between it and the rock.

The Spohn Coal saddles at the slope; it is about 150 yards from outcrop to outcrop. The North Spohn is under the Breaker. These outcrops separate on going Westward 600 yards; then they contract, and at the Swatara they unite at the water-level. On the water-level gangway from Muddy Branch, we met the saddle brought down about 250 yards W. of the Swatara Road. The Lewis and Spohn Coal saddles, at the road on the E. side of Swatara, are not 20 feet apart. The N. dip of the Lewis Coal is here 6 feet thick, and the sound part is an excellent coal.

The synclinal axis of M. Weaver's Peach Mountain Coal is visible on the road just E. of the Little Inn, at the intersection of the Muddy Creek Railroad and the Wagon Road.

LOWER OR LITTLE MUDDY BRANCH, RED MOUNTAIN AXIS.

Here the flexure appears to be single, and has a perpendicular dip on its N. side, and a dip of about 40° on its S. The *Northern* or *Little Lick* axis seems to hold its place N. of the main anticlinal of Red Mountain just mentioned, for at Bettinger's North Mine, near the sawmill on the Muddy Branch, we see the evidences of a saddle in this very line. That there is an axis here is certain, for we have all the indications of a synclinal in the rocks S. of the mine in the cut on the railroad. This cut exhibits S. dips of 30° or 45°, meeting dips seemingly inverted of 80° S.; and S. of this apparent synclinal is a long narrow longitudinal valley, very nearly in the range of the Little Lick anticlinal, which is in all probability the line of the anticlinal connected with the 80° S., or overturned dips on its N.

BETTINGER'S MINES, LITTLE MUDDY CREEK.

The coals opened and worked at Bettinger's or Dundas's Mines on Little Muddy Branch are as follows:—

The Gate Vein, so called. This occurs immediately N. of the anticlinal axis. It is 5 feet thick, and underlaid by 6 feet of slate. The dip is not regular, being in one place flat, and elsewhere in the same dip nearly perpendicular, and again steeply S., and overturned.

Another Gate Vein, between 200 and 300 feet N. of the first, and dipping also perpendicularly, is 4 or 5 feet thick between slate and slate, but contains only 18 inches or 2 feet of coal.

A coal-bed just S. of the anticlinal axis, apparently the S. dip of the Gate Vein, has been worked E. to the line of the estate, and W. about 1400 yards, but it proved faulty nearly all the way. Above it occur two other coals, and then another, called the Black Mine bed, not worked. About 270 feet S. of the last occurs the Tunnel Vein, so called, here mined by a slope-pit. This is the fifth coal ascending from the axis.

Over the Tunnel Vein, at a horizontal distance of 180 feet, lies the Rabbit Hole bed, faulty at the surface, but reached below the water-level by a tunnel driven S. from the Tunnel Vein. To this succeeds the Faust Coal, and beyond it lies another. These South-dipping coals all incline S. about 40°; their strike is S. 80° W.

The Tunnel Coal had been mined, in 1853, W. from the E. line of the estate about 500 yards. It is generally sound, though its thickness is from 4 to 6, or even 7 feet. The Black Mine Coal was not worked. It is overlaid by a pebbly sandstone.

The York Tunnel (*Deep Run*).—This tunnel has been driven N. to the Big Diamond, and the coal has been mined towards Charles Miller's Slope. It is indeed the same bed with that of the slope. About 35 yards further the tunnel cuts the Anderson Coal, and 195 yards still further the Kear's Coal.

COALS ON SWATARA.

About 100 feet N. of the junction of the Swatara Railroad and the Tremont Turnpike, we see the outcrop of a South-dipping grey conglomerate exceedingly like the rock of the Gate and Lewis synclinal trough on Mill Creek above the *Sandrock series*—viz., the *Faust* rock.

It is quite clear from all the evidence that the coals *above* the Egg-conglomerates do not pass

W. in the *Fisher's Basin* beyond Middle Creek, but the lower set, the five inferior beds opened by Mr Werntz on the S. dip of the mountain, run on far to the W., passing behind the Donaldson Mines, and so on to Klinger's Gap, where he has opened all of them. These five lower coals must run on E. a certain distance, but it is doubtful if they are all above water-level at the Swatara Falls axis.

It was, at the date of our researches, a point of much interest to ascertain the place on this anticlinal E. from Swatara Falls, at which the higher strata conceal altogether the upper great Egg-conglomerate. Is it not somewhere between Swatara Falls and Edwards and Morgan's Tunnel? If the upper or Big Coal of Fisher's Basin at Swatara is really the lower or White-Ash Coal of New Mines, as some aver, what is this coal called when it reaches Forestville? Is it not the coal cut in Morgan's Tunnel at the head of Muddy Branch, or the Black Valley Coal of Forestville? It is of some local importance to ascertain where it gets over the Swatara Falls anticlinal.

The Big Vein may be known by its being composed of 6-feet coal, 4 feet of it good; of 1½ feet Bone coal, with 4 inches slate in it; and of 2 to 3 feet clear excellent coal. One of these benches is a reddish-ash coal. The next lower coal-bench or small bed, 1 to 2 feet thick under it, is separated by a rock and 3 feet of Bony coal.

SWATARA COLLIERY, D. P. BROWN & CO.

There are three coal-beds opened here. The middle, 5 feet thick, is a good Grey-Ash coal. The upper is from 10 to 12 feet thick; it averages 7 feet of coal. It has a pinkish ash. There is a third lower seam, which lies not far above the Pea-conglomerate, which rests on the large upper Egg-conglomerate. It is a thin bed.

The 5-feet seam has been driven W. on a N. dip 300 yards. The upper one the same distance on a S. dip. Of this the lower bench is red, and the upper is pinkish ash. At the drift-road, 100 feet above the stream, the coals basin by a sudden or perpendicular reascent of the strata to the surface. The upper of these coals is capped by a singularly rough conglomerate. It is a bed of true Egg-conglomerate, in some places from 8 to 10 feet thick; in others not more than 6 feet, overlaid by shale and sandstone.

MIDDLE CREEK.

On the E. side of Middle Creek N. of the Arch Rock saddle, or in Fisher's Basin, three coals have been opened, all with flat N. and S. dips. Indeed, the coals do not cross the creek Westward:—

1. The Little Grey Coal is shafted in the centre of the basin.

2. A gangway has been driven on the Donaldson Coal in the centre of the basin, at a point facing Middle Creek; it dips gently N. It was at first soft and faulty in the gangway; what its present condition is, we are not informed.

3. The upper coal is the Lomason or Big Coal of Donaldson. It has been mined. The space between the two outcrops of this coal is at least half a mile.

The Grey Coal (the lowest) basins just at the level of the creek, the middle about 50 or 60 feet above the water-level, and the upper 80 or 90 feet above the same horizon. At Fisher's Basin the same three coals have been opened, and partially mined. The Grey bed had 4 feet of good coal.

The upper large coal, or the Big Coal, so called, has not, in Fisher's Basin east of Middle Creek, the coarse Egg-conglomerate over it which we see at Brown's or Swatara.

There are five coals shafted on the mountain on the N. side of Fisher's Basin N. of the Egg-conglomerate or Big Rock, in strata lower than the Grey Coal. Of these, the two lower contain but 6 inches of coal.

The third is 11 feet thick, but soft. Perhaps this is not its true size, as it was but 7 feet in the bottom of the shaft.

The fourth was a 6-feet coal in the shaft, but had not much good coal in it. It was soft and squeezed.

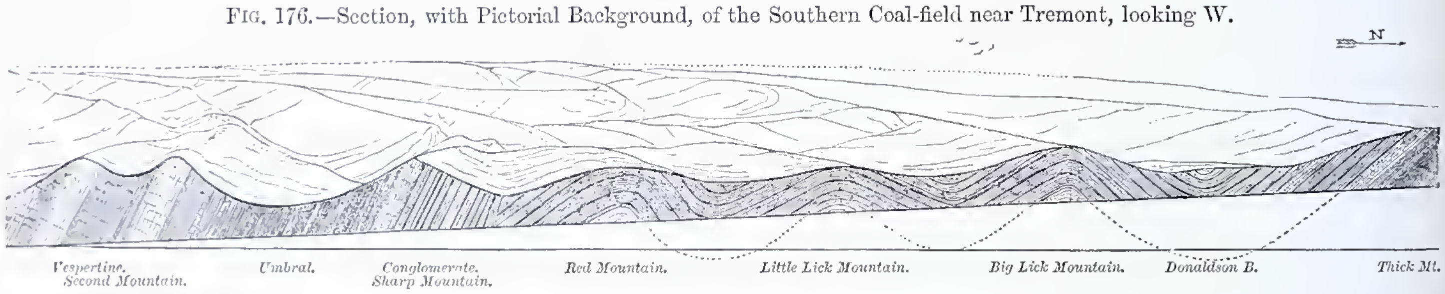
The fifth was soft coal, 2 feet thick, but squeezed, with a conglomerate above and below it. It is seen about 1200 yards N. of the Big Rock. The dip of all these is about 30° S.

CHAPTER X.

COAL-FIELD BETWEEN MIDDLE CREEK AND THE FORKING OF THE BASIN.

As stated in our general preliminary description, the S. coal-field separates Westward into two branches, the N. one being entitled the Bear Valley, or the Wiconisco Basin, and the S. the Dauphin Basin. The place of bifurcation is the kettle or cove at the E. head of Williams' Valley, where the lower conglomerates of the Coal-measures expand in the broad elevated anticlinal table-land of the Little Lick Mountain forking into two monoclinal crests to form the Lick Mountain of the Bear Valley, and the fourth mountain of the Dauphin Basin. Between Middle Creek of Swatara and this place of forking, the general structure of the coal-field is rather simple. Nearly all the undulations which complicate and diversify its structure in the regions E. of Middle Creek, have passed Westward out of the coal-field into the spurs of Mine Hill or West Broad Mountain, and there remain but the three wide and steep flexures of Big Lick, Little Lick, and Red Mountains, diverging Westward with the spreading of the basin prior to its bifurcation. The structure of this portion of the coal-field is well disclosed by the natural section furnished by the valley of Good Spring Creek, which intersects all the three anticlinals. After the sufficiently elaborate description of these several flexures, and their effects upon the strata, it will not be necessary in this chapter to trace again their course, or especially to refer to them, except in connection with an enumeration of the coal-seams which they severally expose. Before proceeding to an account of these, the attention of the reader is requested to the annexed pictorial Section, designed to represent both the geological structure of this W. end of the main coal-basin, and the strikingly close connection which prevails between this structure and its topography, external features or scenery. It is drawn as the district would appear from a balloon suspended in the air E. of Good Spring Creek, and N. of the crest of Red Mountain. The diverging crests of the three anticlinal ridges are seen stretching W. to insulate respectively the Donaldson or Good Spring Basin on the right, and the Swatara or Dauphin Basin on the left, while the Kettle is distinctly shown in the middle of the picture in the distance, itself forking round the high anticlinal knob of Peter's and Berry's mountain. It brings out distinctly the origin of every valley and mountain-crest within the district, showing the valleys to have been excavated in every case in the softer strata, and the ridges and crests to be simply the more projecting waves and ribs of the harder rocks, not quite so deeply eroded. It serves to illustrate, even to the minuter features of the general landscape, the intimate dependence of scenery upon the two geological elements, altitude or dip, and relative softness and hardness of the rocks. This sketch displays the differences of form and depth between the four synclinal troughs into which the basin is subdivided by the three anticlinals, showing the oblique or folded shape of the more Southern one, the inverted dip of all the strata S. of it, and the normal curvature of the other three. The two central basins—that between Red Mountain and Little Lick Mountain, and that between the latter and Big Lick Mountain—are seen rising and heading out from the plateau at no great distance from the Section; whereas the folded one at the base of the Sharp Mountain, and the other deep one at Donaldson at the foot of the Thick Mountain, are beheld stretching far into the distance bounded by their well-defined mountain-barriers.

Fig. 176.—Section, with Pictorial Background, of the Southern Coal-field near Tremont, looking W.



1 bird, Rausch Gap. 2 birds, Swatara Gap. 3 birds, Panther Head.

BASIN OF DONALDSON, OR BASIN *N Q*.

It was shown, in treating of the N. synclinal belts at the Swatara, that neither the Peach Mountain axis O, nor the Branch Dale flexure S. of it, appears in much force at their intersection by that stream. It is probable that they either expire altogether, or become very flat, before reaching the meridian of Donaldson. Indeed, there are no indications of either of these flexures in the ravine of Coal Run W. of Middle Creek. It has been also intimated that the axis N of the Dripping Arch of Middle Creek, the N. boundary of this synclinal belt, rises steadily W., closing up Fisher's Basin N. of it, and merges itself in the gentle S. dips of the long sloping S. shoulder of the Thick or Broad Mountain N.E. of Donaldson. It would thus appear that, if not from Middle Creek, at least from Coal Run westward, the trough is a simple one of a normal synclinal cross-section, wherein the S. dips of the N. side are of an inclination averaging 45°, while the N. dips of the S. side are as steep as 75° or 80°. The position of the synclinal axis is therefore far towards the S. side of the belt; indeed, it passes through the village of Donaldson, and thence Westward along the immediate valley of Good Spring Creek. Under this form, and with little variation in breadth or depth from Donaldson westward, it extends with remarkable straightness as far at least as Klinger's Gap, and without much contraction, indeed, until it passes the watershed between the East and West Bear Creeks.

Coals.—At Middle Creek the number of coal-seams within the basin *N Q*, notwithstanding the probable presence there of the axis P, must be very considerable, and it is still large, perhaps quite as great, at Donaldson, and for some distance further W. It will be seen, upon inspecting the Section of Big Mountain and of Big Lick Mountain, near Donaldson (see Plate III. of the long coal Sections), that besides the entire series of White-Ash coal-seams outcropping in the flank and summit of the Big or Thick Mountain, the basin there embraces an extensive group of Red-Ash beds, the total number opened for both classes, thick and thin, amounting to seventeen or eighteen. At least five of the Red-Ash group have been exposed by proving and mining, in concentric saddles, in Big Lick Mountain. Inasmuch as the coals of the deeper central line of the trough lie under a deep covering of wash or diluvial matter, and have never been opened, we may add at least two or three to the previous enumeration, and count the whole number at twenty: of these, five or six are of large dimensions, and are susceptible of being profitably wrought. The section already referred to, and the profile of the Donaldson Tunnel, here inserted, will furnish the reader with the dimensions, the distances apart, and the dips of all the coal-seams at present exposed here, and will serve as a key for estimating the contents and structure of the basin both E. and W. of Donaldson.

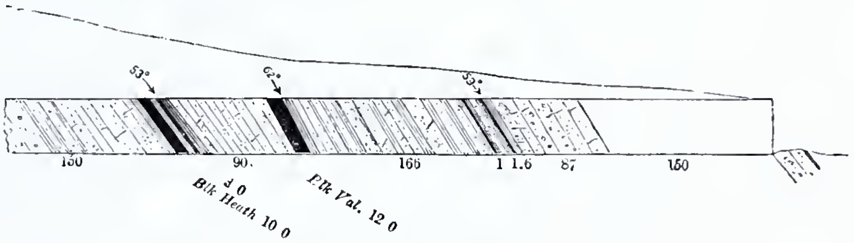


FIG. 177.—Tunnel in the Thick Mountain N. of Donaldson, looking E.
1 *inch* = 200 *feet.*

Thick Mountain Tunnel and Drifts.—The coals here are,—

1st, The Gardiner or Twelve-feet Coal, or Black Valley Coal, worked on the E. and W. sides of the valley; it is quite good coal, but sometimes soft—lies in one bench. The gangways are straight. It has been mined W. one mile, but not worked E. so far; it was cut in the Thick Mountain Tunnel.

2d, The Black Heath Coal is 8 feet thick, and in one bench; it has been mined E. and W. About one mile W. the gangways are straight. It is worked on the W. side chiefly; it also was cut in the tunnel.

3d, The Iron-ore Coal was shafted upon, but was not worked: there was no good coal in it: it is 2½ feet thick, and about 150 feet N. of the Black Heath Coal.

4th, The Big Coal is 16 feet thick on the average; it occurs in two benches of good coal, though somewhat faulty. It has been mined E. half a mile, and W. more than one mile. The gangways are regular and straight.

5th, A ten-feet coal is mined E. 1000 yards, and W. the same distance, and is in one bench. On the E. side the coal is good; on the W. it is faulty for 700 yards.

The Big Diamond coal, S. of all these, is opened and worked by a drift; it has from 3½ to 4 feet of pretty good coal; it was mined but a short distance, and only to the W.

BASIN OF BIG AND LITTLE LICK MOUNTAINS, OR BASIN *Q R*; ALSO LITTLE LICK MOUNTAIN.

The synclinal belt embraced between the two Lick Mountains may be regarded as the prolongation Westward of the very long but somewhat undulated trough of coal strata immediately N. of the Gate Ridge; it is only at Swatara, or perhaps more truly at Middle Creek, that it assumes an independent synclinal structure in the development of its two bounding anticlinals: these seem slightly to diverge going W., making the basin widest about the meridian of Rausch Creek, where, however, it is by no means deepest. The rapid ascent Westward of the anticlinal axis of the Little Lick Mountain, by successively lifting out in that direction the lower Coal-measures, produces, in conjunction with a similar though more gentle rise of the Big Lick axis, a progressive shallowing and flattening of the basin, until at the sources of Rausch Creek it becomes merely a high mountain-trough on the N. slope of the Lick Mountain. From this point—namely, the head of the "Kettle"—it now rapidly contracts and shoals, until, opposite Klinger's Gap, it is little more than a mere broad shoulder or expansion of the same mountain, embracing only the very lowest thin White-Ash coals, alternating with the coarse conglomerates. The following notes of the coal-beds opened and mined at the Good Spring Gap in Big Lick Mountain, and in the N. flank of the Little Lick Mountain, W. of Tremont, will sufficiently exemplify the structure and resources as hitherto developed of the two borders of this basin. Its central deeper portion is almost wholly unknown; but taking its width and the steepness of its bounding anticlinal flexures into consideration, with the farther circumstance that neither of these anticlinals lifts either of the White-Ash coal-seams to the surface till we pass a good distance W. of Tremont, it is obvious that it must be a very capacious trough, holding, in all probability, a greater depth of Coal-measures between Good Spring Creek and Rausch Creek than the Donaldson Basin itself.

BIG LICK MOUNTAIN ANTICLINAL.

This very straight and persistent axis may be traced E. from Donaldson, by the dips and the topography, the whole distance to the Swatara. It is well seen in the dips newly exposed on the Middle Creek Branch of the Mine Hill Railroad; again in the cuts of this railroad, in the same spur further E.; and it is very striking again, in its anticlinal arch, in a cut on the Swatara Railroad, only a few hundred feet N. of the turnpike road. Eastward from the Swatara we could not follow it; but there is good reason to suppose that it is declining and fading away in that direction, inasmuch as we find only S. dips under Llewellyn, and immediately S. of this village, in the belt into which this axis should manifestly be prolonged, if it runs so far.

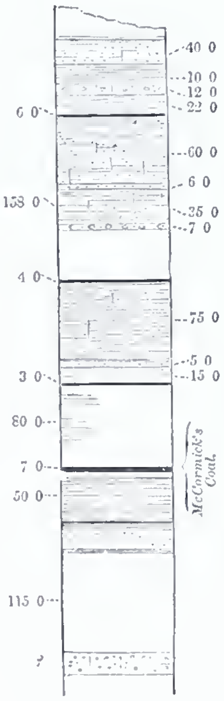


FIG. 178.—Strata in Big Lick Mountain. — 1 *inch* = 200 *feet.*

Coals in the Gap of Big Lick Mountain, Donaldson:—

1. The outside coal on the S. dip is from 6 to 10 feet thick—it has been driven 600 yards or further.
2. The next bed N., also on the S. dip, is 4 or 5 feet thick—it has been worked E. three-fourths of a mile.
3. The small coal has been driven E. only a few yards.
4. A fourth, called McCormick's Coal, is from 1 to 10 feet thick on the S. dip. It was driven 600 yards E. at the date of our observation.
5. A small coal—was mined in 25 or 30 yards. To this succeeds the saddle.

The N. veins are very nearly perpendicular. The equivalent of No. 4, North-dipping, was mined Eastward one-third of a mile, and was about 10 feet thick. The equivalent of No. 2 was also worked Eastward one-third of a mile.

On the W. side of the valley of Good Spring Creek, No. 4 was worked on a S. dip by McCormick and Clark—it was mined in Westward 1 mile; its dip is 65° S., and not less to the end of the gangway. The coal is of a red ash. On the W. side, No. 2 was worked in on the S. dip about 400 yards. Its dip is 65° S. It is a good Red-Ash coal.

LITTLE LICK MOUNTAIN.

The Little Lick Mountain, W. of Tremont, contains three anticlinal flexures, the most Southern of which is obviously the chief one, being traceable to the bold arch of the Egg-conglomerate visible at Rauschville. All of these saddles descend rapidly Eastward: the middle one is apparently the shortest; the two outside ones, especially the most Northern, exhibit very steep N. dips. At the date of our observations there were five separate beds of coal of workable dimensions, proved and partially traced, and the upper or more external of them mined to a considerable extent. In descending order their dimensions are 4 feet, 4 feet, 7 feet, 5 feet, and 7 feet. The getting access to these coals has not been an easy matter. To tunnel into them from a low level on the S. side of the mountain would have implied a large expenditure, as the S. dips are comparatively gentle, and the requisite tunnels there must be long. The greater steepness of the N. side of the hill, and closer proximity of the North-dipping coal-seams, naturally led to their being first entered by tunneling from that quarter; but this resulted, as might have been anticipated, in much disappointment. As usual, the flexures having one gentle and one perpendicular dip, the perpendicular strata have been found to be much squeezed, and the coals therefore—namely the second 4-feet bed, and the 7-feet seam beneath it, and the next coal below this again—have all been found so faulty as scarcely to repay the cost of mining. The method of entering these coal-beds has been by short tunnels, some from the exterior, others from within gangways already cut, but all planned to reach the next interior coal near its place of saddling or arching over and round its anticlinal axis, the object being to command as soon as possible a double line of gangway, or rather to get round the point or nose of the West-dipping saddle in the South-dipping portion of the coal-bed. This mode of entering the mountain—assuming a long tunnel from its S. side to be too costly—appears to be, after all, the most feasible, and would have proved eminently successful, if the mountain, in place of containing three saddles, possessed but one. In that case the gangways in the South-dipping coals could have been extended indefinitely to the W., but the existing more complex state of things will turn these gangways round the ends of the synclinal basins and Eastward into North-dipping strata, until, by successive windings through comparatively sound South-dipping coal, and very faulty soft perpendicular-dipping coal, they at last reach the S. side of the main Southern axis, along which they may proceed without further check. Such being the inevitable conditions attending the mining of these concentrically enclosed coals from the N. side of the mountain, it is obvious that to extract the coal from at least the S. part of the ridge, the method by tunneling from the S. would be altogether the most feasible.

Spangler's Four-feet-thick Coal is penetrated by a tunnel near the point of its anticlinal flexure at Tremont. The tunnel enters the strata from the N. side of the ridge, running 145 yards S. 64° W. in the outside coal-bed; it then turns abruptly towards the S., and cuts slate and sandstone through 121 feet to the other 4-feet seam, reaching this bed 92 feet W. of the point of its saddle. Another tunnel farther to the W., at a higher level, cuts Spangler's Four-feet Coal, and reaches the 7-feet seam inside of it, very near the point at which this seam in its turn saddles over its axis at the tunnel-level; and a third tunnel, 80 yards in length, starts from the gangway of the N. dip of the 7-feet seam, and, like the rest, directed S., cuts the measures between the 7-feet bed, and the coal next inside of it, which it meets in a similar position, namely, a little W. of the point at which it swings over the declining anticlinal axis.

BASIN OF LITTLE LICK MOUNTAIN AND RED MOUNTAIN.

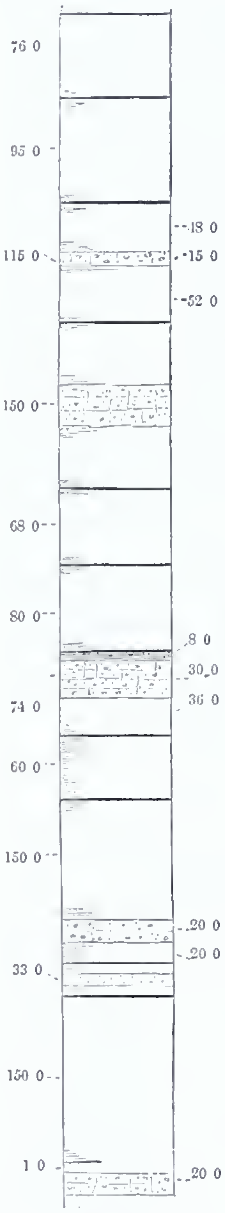


FIG. 179.—Strata in Red Mountain.—1 *inch* = 200 *feet.*

As intimated in a former chapter, this synclinal trough expands rapidly Westward from the Swatara, and rises as it expands, until it lifts itself out from the broad plateau around the S. side of the Kettle. It is intersected by the valley of Good Spring Creek at Tremont, and by that of Rausch Creek, 2 miles further W. From the Middle Creek Railroad at Swatara, to Tremont, the developments within this basin are very few, and its structure is obscure; but W. of that village its contents are better defined, the topographical features being more distinct, the mining explorations in Little Lick Mountain and in Red Mountain, at the gaps of Good Spring and Rausch Creeks, revealing to us some of its coal-seams. It has been already stated that the Red Mountain or Gate Ridge discloses at Good Spring Creek not fewer than eleven seams of Red-Ash coal dipping N. into this basin at a very steep angle; and in our previous description of the Little Lick Mountain, the N. side of the basin, or the S. flank of that ridge, was shown to contain at least six outcrops of coal-beds of workable dimensions. (See Section of Red Mountain and the annexed vertical column of North-dipping beds.) The probability is, that the total number, big and little, at Good Spring Creek, is from thirteen to fourteen, for the synclinal axis of the basin cannot be far N. of the base of Red Mountain. This line of lowest depression of the trough does not range centrally along the belt, but maintains a direction very nearly parallel to the anticlinal or crest-line of Red Ridge all the way to Rausch Creek, and even to Lorberry Creek, as may be seen by inspecting the Rausch Creek section in Plate III. The North-dipping coals of the S. side of the basin in the N. side of Red Mountain, maintain their steep or nearly perpendicular dips as far W. as Rausch Creek, beyond which they flatten as they pass the head of Lorberry Creek, to join the South-east-dipping corresponding strata of the W. end of the basin. From Good Spring Creek the coal-beds rise out towards the W. in successive concentric basins or spoon-shaped troughs, some of which are even vaguely indicated in the topographical features of the valley. This structure is eminently adapted to a successful mining of the thicker coal-seams, since shafts or slopes, sunk in the vicinity of Tremont, will drain extensive fields of gently South-dipping coals all the way to Rausch Creek. The Red-Ash Coal-measures occupy the entire breadth of this basin as far as Rausch Creek, excepting a wide triangular area N. of the axis on the high table-land of the Little Lick Mountain, where the White-Ash coals, down to the coarse Egg-conglomerate, at the anticlinal of that mountain, spread themselves out in a very gentle Southerly dip. On Rausch Creek the total number of coal-seams left within this basin would appear to be about seven. Three of these, including Kechre's and Wells' coals, at the passage of the Red to the White-Ash groups, are seen spanning the anticlinal axis of the Red Mountain above the water-level, and reascending on the N. side of the synclinal, with a S. dip of not more than 20°. Next beneath them occurs the Big Coal, so called, identical probably with the large seam of Donaldson. This is some distance below the water-level of the valley at the Red Mountain anticlinal axis, but on the N. side of the basin it ascends from the water-level, with a long and very gentle slope to its outcrop on the high plateau of the Little

Lick Mountain. The other inferior seams may be seen dipping S. at a still lower angle, with proportionately still longer breasts as we ascend the valley to the well-exposed broad anticlinal flexure or arch of the central ridge of the mountain.

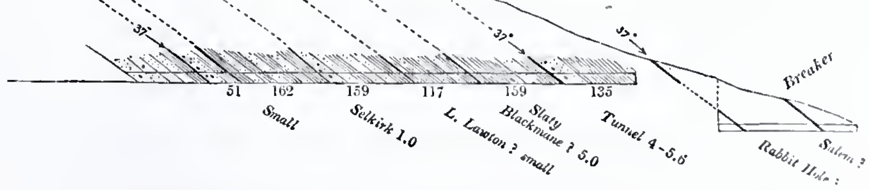
BASIN OF RED MOUNTAIN ANTICLINAL AXIS AND SHARP MOUNTAIN.

That portion of the deep straight synclinal belt or basin which lies between the Swatara Gap in the Red Mountain, and the gap of Fishing Creek in the Sharp Mountain, maintains well its average breadth and extent of Coal-measures as far W. as the notch in the Sharp Mountain by which the Swatara Creek quits the coal-field; but from this latter point the trough commences to contract and rise by the expansion and lifting of the Red Mountain axis, until at the Fishing Creek Gap it is reduced to probably not more than two-thirds the width and depth it possesses in its Eastern half. As far W. as the Tremont Gap in Red Mountain, the South-dipping coals of the N. side of the basin incline S. at angles as high as 45° and 55°, and they retain this dip, or even a steeper one, indeed, as far as the valley of Rausch Creek. At the passage of Lorberry Creek across the basin, the S. dips become more gentle, but the strata maintain an average slope of 45° past the sources of Fishing Creek, and Westward for a great distance along the N. side of the Dauphin Basin. Except at the Tremont or Good Spring Gap, and at Rausch Creek, the coal-beds of this N. side of the basin have hitherto been very imperfectly developed by mining or experimental shafting. In the Tremont Gap, and apparently for a long distance E. and W. of it, the Coal-measures of the S. slope of the Red Mountain are, for South-dipping strata, unusually disturbed or faulty. The irregularity is chiefly of the nature of a squeezing and sliding of the coal-seams within themselves, rendering them very generally unfit for mining. This condition extends indeed all the way from Muddy Branch to Lorberry Creek, and prevails to a partial extent opposite Fishing Creek and into the N. side of the Dauphin Basin. Its cause is obvious enough: the strata of both the Sharp Mountain and of the N. slope of the Red Mountain anticlinal dip perpendicularly, and are in places even overturned; the whole wave of the strata, from the crest of Sharp Mountain to the N. base of the Red Mountain, being in fact a greatly compressed undulation, with a steeply-inclined South-dipping axis-plane. It is obvious that in the sharp close flexing of the superficial softer Coal-measures within the trough of the less yielding underlying thick beds of conglomerate, the upper concavely-compressed materials were forced to yield in their planes of least resistance, or most feeble cohesion—that is to say, in the relatively tender coal-beds themselves.

RED MOUNTAIN OR GATE RANGE.

At Tremont the flexure of the strata in Red Mountain is, to all appearances, a single regular normal anticlinal arch, curving into the perpendicular on its Northern side, and to a dip of 45° on its Southern; but it is rather sharp, and even a little dislocated, at the crown of the arch. The South-dipping coals, in the vicinity of the Tremont Gap, are generally squeezed and faulty, the least disordered of the series being the Southernmost. This has been mined on both the E. and W. sides of the gap.

Fig. 180.—Section of S. side of Red Mountain at Hebbard's Tunnel, 2 miles E. of Tremont, looking E.—1 *inch* = 400 *feet*.



West Salem Colliery, Red Mountain, $2\frac{1}{4}$ miles E. of Tremont.—A tunnel was here driven 290 yards Southward into Red Mountain ; the dip is 37° S. This mine was not successful ; all but the first and last coals were in fault, and the first has a low breast. It is a singular circumstance, that, with a S. dip so gentle as 37°, the coals should be so squeezed and faulty ; but such is also their condition at the Tremont Gap of Red Mountain, and indeed it belongs to this ridge as a characteristic throughout much of its W. portion. Sharp Mountain, though with overturned strata, is very regular in all this vicinity in its line of crest, and in its form; and from topographical indications, it seems to be comparatively exempt from dislocations.

Sharp Mountain Coals, their Number and unusual Position.—The S. side of this basin, or that included in the N. slope of the Sharp Mountain, embraces a thick series of Coal-measures, containing apparently nineteen or twenty separate seams, counting with the larger ones those of 1 or 2 feet in thickness. From the squeezing attendant upon the inversion of the strata above alluded to, very few of these are in a permanently minable condition, nor are we sure that we know the average dimensions of a number of them.

Throughout this Western district of the coal-field, all the lower coals lie outside, or to the S. of the main or higher crest of the Sharp Mountain, or of those hard and massive ribs of coarse conglomerate, which, at the passes of Swatara, Rausch, and Lorberry creeks, constitute the comb of the ridge. This position, so unlike that which they observe further E. in the coal-field, where the main crest of the mountain is the S. limit of all the coal, is due to a remarkable change in the type and composition of the lower Coal-measures in their extension Westward. Instead of consisting, as at Pottsville and farther E., in the lower 800 feet or so of a large proportion of ponderous and pebbly strata, interleaved with coarse sandstones and relatively little shale, and no coal-seams whatever beyond one or two impure layers 2 or 3 inches thick, the group here embraces an alternation of conglomerates and sandstones with numerous beds of coal-shale and coal itself, converting the non-productive underlying Seral conglomerate into a true coal-bearing formation, or a lower productive group of the Coal-measures. Our engraved Sections, illustrating the state of things at Swatara, Rausch, and Lorberry gaps, show that the main mass of the Sharp Mountain there includes two principal ribs or groups of thick beds of the coarse conglomerate, one adjacent to the Umbral red shale, the other further N., eight or ten coals higher in the series ; it is to these two solid ribs that the mountain owes its two craggy crests, which, adjacent to the river-gaps above mentioned, are excessively torn and precipitous. The condition of things now described prevails, under modified features, throughout all the Western districts of the Southern and middle coal-fields; namely, in the conglomerate measures of the mountains bounding the Dauphin, the Wiconisco, and the Shamokin basins. A fuller description of the special phases assumed by these lower coal-strata in each of those Western districts is reserved for a future chapter, but this is the appropriate place to note that this remarkable alternation of productive coal-seams with the lower layers of conglomerate is a feature characteristic of the formation everywhere W. of the meridian of Tremont and Ashland, augmenting progressively as we advance to the W. and N.W. It may be due to either of two causes ; an intercalation of beds of coal among the beds of conglomerate and sandstone constituting the barren Seral conglomerate of the country Eastward, or a thinning down of that conglomerate, and a commensurate increase of pebbly matter in the sandstones of the lower productive Coal-measures. The first assumption implies a comparative permanency in the conglomerate, and an insertion of new coal-seams between its subdivisions ; the second supposes a comparative constancy in the coal-beds, and an intrusion of conglomerates or conglomeritic matter between them. No explorations, short of extensive and connected mining and coal-shafting, will effectually determine to which cause we are to impute the change of type in the strata. Most probably it will prove to be the result of both causes combined ; for it is incompatible with a sound theory of the production of our Coal-measures, to take for granted that either class of deposits—the coal-beds or the mechanical sediments interstratified with them—are continuous over very wide spaces. I am inclined, however, to attribute the alternation of coal and conglomerate, near the base of the formation, to the actual introduction, in the Western district, of fresh beds of the former during the deposition of the latter, and to those beds thinning out and disappearing from absence of the requisite vegetable matter or conditions of vegetable growth towards the E. Among other reasons for this opinion, I will suggest in this place two apparently conclusive ones. The one is, that we may actually trace some of the valuable thick coal-seams of the Western end of the Shamokin and Pottsville basins, from station to station, Eastward, under continually-declining dimensions, until they actually thin down to insignificant layers. The other argument is, that the W. or N.W. is not the usual direction towards which the fragmentary or pebbly matter of the formation is known to increase in relative quantity and coarseness, but, on the contrary, is the very quarter towards which all the mechanical sedimentary matter of our coal-formation grows progressively finer and less abundant.

Between the red shale on the S. and the axis of the oblique folded synclinal flexure at the N. base of Sharp Mountain, we may count twenty separate beds of coal of all thicknesses, from 1 or 2 feet to 10 or 12 feet. At no one of the three gaps W. of Tremont have the whole of this series been as yet exposed, but by collating the assembled facts of the three Sections we are enabled to identify the number here specified. Nine out of the twenty occur between the main thick rib of conglomerate, at the base of the whole formation, forming the S. crest of the mountain, and the thinner bed of even coarser pebbly rock belonging to the N. crest : of these nine, five are apparently too thin for mining, and the other four are of good workable dimensions; the lowest is from 4½ to 6 feet thick, the next 10 or 12 feet, the next 6 feet, and the fourth, called here the Peacock Coal, is also thick, but of very variable size. Between the coarse Egg-conglomerate of the N. crest of the mountain, and the synclinal axis near the E. and W. reach of the Swatara, five of the eleven coals developed would appear to be thin ones, while of the remaining six the Zimmerman is 4½ feet thick ; the Umberhower, two coals higher, is 3½ feet ; the next coal is 4½ feet ; the next, a squeezed coal, is 4½ feet ; the next is 5 feet ; and the Grey Coal, the highest of the whole series, is from 12 to 14 feet.

The exact position of the synclinal axis of the basin is not clearly marked E. of the Swatara Gap, but it coincides nearly with the S. foot of Red Mountain : at the Rausch and Lorberry valleys it is well defined, and is there somewhat nearer the anticlinal axis of Red Mountain.

Throughout all this district—indeed, from the Pottsville Gap of Sharp Mountain as far as Dauphin County—the strata of Sharp Mountain are, as already intimated, tossed N. beyond the perpendicular ; in the central part of the ridge, composed of hard unyielding beds of conglomerate and sandstone, the inversion at the notches connected with the Swatara amounts, on an average, to about 15°—or the S. dip, in other words, is 75° ; but the softer and more easily crushed strata of the N. slope and foot of the mountain have been pressed down by the forward or Northward motion, at the time of the folding of the trough into a considerably more inverted or lower

S. inclination. A little study devoted to the Sections embodying our observations at Swatara, Rausch, and Lorberry gaps, will enable the reader to apprehend clearly all the interesting relations of the coals there developed, to learn what is known of their respective thicknesses and distances apart, and torecognise their degrees of inversion ; it will satisfy him that this part of Sharp Mountain is scarcely more promising a field for largely-planned mining enterprise than the other portions of the same ridge further E., which I have already reviewed.

CHAPTER XI.

WICONISCO AND DAUPHIN BASINS, OR THE WESTERN BRANCH BASINS OF THE SOUTHERN COAL-FIELD.

The great Southern coal-field forking beyond the broad anticlinal plateau of the Little Lick Mountain, the Coal rocks extend Westward in two long and slender diverging troughs, the most N. of these—the Wiconisco or Bear Creek Basin, a prolongation mainly of the basin of Donaldson—and the widest and shortest of the two, tapers to a point in the middle of Lyken's Valley, about 4 miles W. of Gratztown. Its N. barrier, the Thick or Bear Mountain, is cleft nearly to its base at Klinger's Gap, giving outlet to East Bear Creek. Its S. barrier is breached, but not to so low a level, at Bear Gap—a high notch, which discharges the West Bear Creek into the Wiconisco. From Klinger's Gap to the synclinal knob of the Short Mountain, in which it terminates, the bed of this valley rises progressively, until it terminates in that mountain-summit, and throws out its lowest coal-seams in the long spur descending Westward from it.

The Southern or Dauphin Basin, though not more than half the breadth of the Wiconisco trough, possesses nearly twice its length. There is no breach of any magnitude in its N. barrier, a high regular monoclinal mountain-ridge, which, being the fourth in order N. from the Kittatinny Valley, is commonly called the Fourth Mountain. Its S. barrier, the Sharp Mountain, retaining the narrowness and acuteness of crest which elsewhere distinguish it, is broken by six steep and narrow ravines, or high notches, which drain the waters of the basin from a high interior level Southward down into the exterior longitudinal valley of Stony Creek. The first of these, W. of the forking of the basin, is the Gap of Fishing Creek ; the second, nearly 4 miles W., is the Gap of Black Spring ; the third, 1¼ miles further, is called Gold Mine Gap ; the fourth, 3½ miles further W., is Rausch Gap ; the fifth, 5 miles beyond, is Yellow Spring Gap ; and W. of this 3½ miles is a notch at a still higher level, which bears the name of Rattling Run Gap. From this last ravine or outlet to the end of the Coal-measures in the high narrow synclinal ridge in which the slender mountain-trough terminates, by the coalescing of its two barriers, the distance is about 12 miles. The final closing together of the North and South-dipping lowest members of the coal strata would appear to be between 5 and 6 miles E. of the little town of Dauphin on the Susquehanna. I proceed to a sketch of the Coal-measures of the Northern or Wiconisco Basin.

WICONISCO, OR BEAR VALLEY COAL-BASIN.

This, the Northern of the two Western branches of the great Southern Anthracite Basin, is bounded on the N. by the monoclinal South-dipping ridge called the Bear Mountain, a prolongation of Broad Mountain; and on the S. by a monoclinal North-dipping ridge called the Big Lick Mountain, prolonged from the anticlinal Big Lick Mountain of Donaldson. Its entire length from Donaldson's Colliery, or where Good Spring Creek leaves it, to its Western end, is about 20 miles, and its average maximum breadth between Donaldson and Klinger's Gap is a little more than 1 mile. Good Spring Creek and Rausch Creek of Swatara drain its Eastern portion; its middle division is watered by an East and West-flowing brook, which unite and pass Northward through Klinger's Gap to the Mahantango; while its Western end discharges a rivulet through Bear Gap into the Wiconisco. By these three avenues must the valuable mass of coal enclosed within this trough find egress to the markets. A railroad extends to Donaldson's Mines, and might be readily prolonged to the summit at the source of Good Spring Creek. Another railroad conveys the coal from Bear Gap to the Susquehanna, and a third through Klinger's Gap has been in contemplation.

From a point a little W. of Klinger's Gap to the end of the basin, the valley is a simple synclinal trough, the strata dipping inward on both sides at an angle of about 45°. But opposite and Eastward of the Gap, the S. side contains the anticlinal flexure of Big Lick Mountain, already described, which produces a bench or elevated flat tract on the N. side of the mountain. The N. and S. dips forming this anticlinal are well exposed in a deep and wild ravine, indicated on the Map by a stream S.E. of the gap.

This portion of the basin contains an enormous quantity of coal, and even a large amount above the water-level. A favourite idea was at one time cherished by some persons to tunnel the Southern barrier of the valley at a point a little W. of the commencement of the Section; and there can be no question that a tunnel, once properly constructed there, would give access to a most productive coal-field. This was actually begun a number of years ago. The great length of tunnel necessary to reach the best beds of coal, nearly three-fourths of a mile, and the great hardness of a large portion of the strata, would prove serious impediments, demanding an enormous outlay; and it should be well considered whether the two other channels of outlet, partly executed by nature, and to a great extent already improved by art, may not, when perfected, suffice for all the wants of the region.

Klinger's Gap Coal Strata.—The strata of the N. side of the Basin are well exposed at the notch called Klinger's Gap. The details there collected, taken in connection with those of Donaldson's Colliery on the one hand, and those of Bear Gap on the other, will give a sufficiently correct notion of the general contents of the basin. Towards the middle of the valley higher coals occur than any met with at these localities, which, however, represent all the most important or lower beds, or those which, rising highest above the water-levels of the district, are of easiest access, and which are at the same time the thickest, the soundest, and the most valuable for the quality of their fuel. These lower White-Ash coals form a belt on each side of the valley, where they rise high above the stream, outcropping in the flanks of both the enclosing mountains.

Klinger's Gap.—At this important breach in the N. barrier of the Wiconisco Basin the coals are in ascending order.

No. 1. 60 feet from the red shale is a small 2½-feet coal shafted on.

" 2. 90 feet further a drift on a 7-feet vein, worked 8 or 10 years ago. The coal was good at first, but squeezed; the gangway was worked in 173 feet; the dip is rather more than at Donaldson.

" 3. 87 feet to the drift on a 5-feet thick coal, 100 feet in, with only 2 feet of good coal.

" 4. 192 feet to an old drift on a 6-feet-thick bed of good coal, worked in 150 feet.

" 5. 130 feet to a small coal, with a drift.

" 6. 288 feet to a small coal shafted into on the mountain.

" 7. 372 feet to a coal 11 feet thick; the 10 feet of Donaldson worked in some distance. It is immediately on the top of a coarse Egg-conglomerate; over it lie 12 feet of slate, on the top of which is 4 feet of solid coal, worked at the second drift, but only 5 yards in.

" 8. The Iron-ore coal, 2 feet, is shafted on the mountain 60 feet N. of the Lomason or Big Vein.

" 9. The Lomason or Big Coal, 10 feet thick, in two benches, the top 4 feet, bottom 6 feet thick; the ashes of the bottom are white, of the top grey. It was worked in 50 yards; the coal is good.

" 10. 100 feet to a 4-feet coal—the Black Heath Coal, locally the Peacock; worked in 300 yards; very good; dip 58° S.

" 11. 20 feet slate to the Black Valley Coal, in drift, it is 24 feet thick. It averages 16 feet of coal, and has 5 feet of impure coal in the bottom; it was worked in for 150 yards.

" 12. 40 feet to a 4-feet bed of good coal, with a sandstone top; the gangway ran in from 12 to 15 yards; it had fallen in.

" 13. 40 feet to two small coals, shafted on; 2 feet thick each, and about 6 feet apart.

(See Section of the E. side of the gap, Plate III. of Sections.)

A plate of dark-grey argillaceous iron-ore, very carbonaceous, and full of vegetable fossil forms, lies immediately over coal No. 8 of our Section. It is about 8 inches thick, and is separated from the coal in the roof of which it lies by about 12 inches of black carbonaceous laminated slate. It has been erroneously called the *Black Band Iron-ore.* It is extremely interesting from its partial resemblance to the proper blackband of Scotland, to the admirable qualities of which much of the marvellously rapid progress which that country has recently made in the smelting of iron may be attributed. Should this stratum of the Bear Valley Basin prove to be generally diffused, and of profitable thickness for smelting, its proximity to the anthracite as a fuel would confer upon it the highest economical value. Promising to be superior in quantity and cheapness to many other of the bands of iron ore yet met with in the anthracite region, I have given it a very careful examination, and the following are the results: The layer of ore is strictly a continuous sheet within the roof-slate of the 3-feet coal-bed next N. of the Lomason seam, and in such close proximity to the coal that they might be both mined together, and the expense of getting the ore thereby materially lessened. Its maximum thickness is 12 inches. This it maintains throughout the length of the coal-drift on the E. side of the gap, which is 300 yards long. On the W. side of the notch its thickness appears to be less, probably not more than 7 or 8 inches. The value of the ore for conversion into cast-iron is materially impaired by the presence of a considerable proportion of *sulphur*, certain parts of it being decidedly pyritous.

With a view to ascertain the permanency of this band of ore, I examined the locality of the old opening of the great bed about 1¾ miles E. of the gap, and there discovered it, but was convinced, so far as I could infer from the magnitude of the outcrop, that it undergoes, even in that district, a material reduction in thickness. Tracing the belt containing it to Donaldson's Mines, it was ascertained that it is there altogether absent, or only very faintly indicated; for while the coal and roof-slate, which it should accompany, are well exposed, and have indeed been opened with a view to its discovery, the ore itself could not be found. We shall presently perceive that it is not more persistent in the opposite or Western direction, and that no trace of it has been detected at the mines near Bear Gap, though its coal-bed is readily identified. What its more precise limits may be in the vicinity of Klinger's Gap, it is impossible, in the present undeveloped condition of the locality, to ascertain without patient and prolonged research. Should it retain its fullest dimensions of 10 or 12 inches, and prove pure enough for smelting, the great cheapness with which it may be mined must, I think, recommend it as a promising basis for iron-works at the gap. But even with a thickness of 12 inches, the limited district within which it possesses this size would soon become exhausted, unless the other argillaceous ores should prove to be likewise abundant and continuous; and of this fact we are at present in entire uncertainty.

Bear Gap.—The natural transverse section of the coal-formation at Bear Gap exposes the strata in the South Mountain, dipping N. at angles varying from 50° to about 30°. It is probable that this inclination, which is a favourable one for cheaply extracting the coal, continues with the strata to near the W. end of the basin, growing gradually less towards the extremity. The average dip of the same rocks in the North Mountain is S. about 40° or 45°, and this steepness also declines as we advance to the W. On the N. margin of the coal-field, towards its W. end, the inclination of the beds is quite gentle, a condition which may be highly profitable, as giving a great breast or slant length to the coal-seams above the water-level of the interior valley.

The coal-formation at Wiconisco appears to contain two groups of productive coal-beds, together with a few thin and profitless seams in the intervening strata. The lower group consists of four coals, the first beds met with on entering Bear Gap from the S. These are enclosed between the conglomerates and sandstones which immediately overlie the red shale formation, the lowest coal of all, having but about 150 feet of those rocks between it and the red shale.

The upper coals occur in the very centre of the basin, in the highest strata of the section, and are intersected in a crushed state in the tunnel. These lie among hard grey argillaceous sandstones and compact silicious slates. They are three or four in number, and are in their least disturbed state on the N. side of the synclinal axis, or turn of the strata, in the middle of the basin. At the tunnel, and for a few hundred feet E. from it, they are squeezed, and in a condition unfit for mining; but further forward, in the same direction, they assume their regular full dimensions, and are yielding on their S. dips very excellent coal.

Both the N. and S. outcrops of the lower group will be found several hundred feet *outside* of the actual summits of their respective mountains, and a considerable distance down from their crests.

This lower series will probably be found to extend to the termination of the coal-basin, beyond where the two mountain-crests unite, and to sweep their lines of outcrop through the E. part or club end of the mountain-spur in which the basin ends, thus forming an outer belt encircling the whole coal-field. Each of these coals spreads, of course, under the entire basin We may estimate their average height of breast above the level of the gap at between 400 and 700 feet, increasing as we approach the extremity of the basin.

Coal 1.—The lowest of the whole group varies in its thickness, which, estimated between its top and bottom slates, is from 5½ to 7 feet. It will not be fair to count upon more than 5 feet of good coal in it, even where it is unaffected by faults.

Coal 2.—East of the Wiconisco Gap this bed has a thickness of 10 feet, and may be estimated to produce, when sound, about 8 feet of good coal.

Coal 3.—This bed has a maximum thickness of 4 feet.

Coal 4.—Measures about 3 feet, and is, I imagine, nowhere rich enough in pure coal to be profitably wrought.

Between 5 and 6 tons of coal to the square yard of surface may be considered as the maximum yield of this group of beds, where they are unaffected by a squeezed condition of the strata; but so prevalent are faults or steps along their lines of outcrop E. of Wiconisco Gap, that I think it will be prudent to make an abatement for soft and unmerchantable coal, and to estimate the actually available quantity as not more than 4 tons to the square yard, or about 20,000 tons per acre.

Some, if not all, of these lower seams have by this time been reached by the tunnel and the North Mountain.

The upper series of coals is of much more restricted limits than the lower, just described. They have their N. outcrops at Bear Gap, over the N. half of the tunnel, or immediately N. of the central line of axis of the basin. Their S. outcrops, from being near the bed of the stream, which, in approaching the gap, encroaches more and more S. of the middle of the basin, are deeply covered with debris, and have not been yet detected. In the tunnel, as already said, all of these coals are squeezed out by faults, but Eastward they have been wrought, and are of the following dimensions :—

The *Hoffman* Coal, the lowest of this group, is intersected near the N. end of the tunnel, and is E. of this locality about 4 feet thick. Its outcrop is rather high on the inner slope of the North Mountain.

The *Air-Hole* Coal, the next overlying bed of profitable size, is pinched to a thickness of 2 feet in the tunnel, but a few hundred feet Eastward it measures 6 or 7 feet.

The *Etting* Coal shows an average thickness of about 8½ feet, where it has been mined 500 or 600 feet E. of the tunnel.

The *Pat Martin* Coal, the highest of the series at the tunnel, has, when regular, an average thickness of from 5 to 7 feet.

Where these coal are sound, they are all of a valuable size, but from their position so near a much-compressed synclinal axis, or turn of the dip in the basin, I fear that, at least, in the vicinity of Bear Gap, they will be found in a more damaged or soft state. The space which they occupy in the basin will be found to contract going Westward, and they will not be seen to extend to the head of the valley.

The Hoffman Coal ranges furthest Westward and occupies the largest area between its N. and S. outcrop, and it may reach nearly to the point where the two mountains coalesce. Each of the others, taken in the ascending order, will have a more and more restricted area, and the two uppermost, the *Etting* and *Pat Martin* Coals, cannot, I think, be prolonged very far Westward of the tunnel.

What amount of merchantable coal this upper group may contribute it is not possible to say, until a greater extent of superficial mining enables us to trace the actual outcrops of the seams.

So also it would be idle to attempt at present an estimate of what is by far the most important practical consideration relating to such a coal-field ; the amounts of coal immediately accessible at different points above the water-levels of the basin, and the quantities procurable by tunnels, shafts, or other artificial inlets. These results depend on data only procurable by close instrumental surveys, more appropriately conducted by the proprietors of estates than by the Geological Survey.

Looking at our Section of the Wiconisco Basin at Bear Gap, the conversion of the Seral conglomerate of the E. half of the Pottsville Basin into productive Coal-measures of the ordinary type, is even more conspicuous than in the Sharp Mountain west of Tremont. In the entire thickness of the Southern or Lick Mountain, the amount of coarse pebbly rock does not constitute more than one-tenth of the entire body of the strata, the chief mass of which consists of argillaceous sandstones and soft shales. The lowest bed of all, or that in immediate contact with the Umbral red shale, has a thickness of about 40 feet, while the other pebbly beds are between 20 and 30 feet thick. A hard stratum of sandstone about 50 feet in depth forms the main crest of the South Mountain, whilst the lowest conglomerate produces a bench or high terrace upon its S. flank. Between this conglomerate outcrop and the main crest all the four coals of the lower group rise to the surface upon the outer terrace, while the other four outcrop at a lower angle averaging 30° N. upon the long gentle N. slope of the mountain between its crest and base in the valley of Bear Creek.

Opposite Bear Gap there is a narrow, sharp, compressed anticlinal flexure N. of the middle of the valley, which extends, in all probability, from near the W. extremity of the coal-field a long distance Eastward. It produces of course two synclinal turns of the rock, where otherwise there would be but one, and is the main cause of the pinched and crushed condition of nearly all the coal-seams of the centre of the basin. Whether it is merely superficial, or extends throughout the thickness of the formation, it would be idle to conjecture, until a greater extent of deep mining makes us better acquainted with the nature of these sharp surface-undulations. This narrow anticlinal turn or sharp saddle, and the two synclinal axes embracing it, are all intersected in the Bear Gap Tunnel, which, passing beyond them, penetrates the South-dipping coals of the North Mountain, where there is reason to presume the coal will be in a much more merchantable condition than in either the Bear Mountain or the centre of the valley.

THE DAUPHIN BASIN.

In describing the Southern of the Western divisions of the First Anthracite Basin, I shall avail myself in part of the data collected and published by the late Richard C. Taylor, Esq., of Philadelphia, an eminent and very skilful practical geologist and mining engineer, by whom this district was originally investigated. While employing his details, I must observe that my own later observations have shown me that the thicknesses assigned to some of the coal-beds are too great. A preliminary generalised view of the whole district will aid the geological student, by a clear conception of its structure, to a sound notion of the conditions under which the coals exist.*

This long and narrow trough of Coal-measures is an elevated mountain-valley of simple synclinal form, having for its Southern barrier the crest of the Sharp Mountain, and for its Northern that of

---

* If opportunity permits, I shall introduce into the Appendix some recently gathered and more correct results respecting the Dauphin Basin and its coal-seams.

Fourth Mountain. From the gap of Lorberry Creek to its W. termination in the synclinal knob which points towards Dauphin, its length is about 28 miles. Between Lorberry Creek and the West Rausch Gap, a distance of 11 miles, this basin, between one outcrop of the conglomerate to the opposite, diminishes in width from about 6000 to 4000 feet, and Westward from the latter locality it continues to contract until the whole becomes a mere narrow belt in a single synclinal ridge, which terminates within 2 miles of the Susquehanna River. Advancing Westward, the general bed of the valley progressively rises, until, where it is within 10 or 12 miles of the river, it attains a height of 1200 or 1400 feet, and it retains this elevation to its termination. It is not so much a valley in its form as a high narrow plateau, belted on each side by a narrow crest only slightly elevated above the general plain. The close proximity of the two massive barriers of conglomerate have preserved its softer coal-rocks from any steep general excavation by diluvial waters. Near every notch in its S. barrier, the bed of the valley, both to the E. and W., is trenched by the waters to a much greater depth than elsewhere. By these gaps, which are confined to the Sharp Mountain, the coal may find a ready outlet into the longitudinal external valley of Stony Creek, a railroad having been constructed, with branches and planes penetrating each gap, to convey it to the Susquehanna River. The basin holds throughout its length the features already represented as belonging to it at the Lorberry. The strata composing its S. half are all in a perpendicular, or even an inverted position, while those of the N. side dip S. at a high angle. As far nearly as the Yellow Spring Gap this vertical dip of the Sharp Mountain strata continues, and indeed the beds are in some localities so much inverted as to dip S. 70° or 80°. In the same distance the S. dips of the other side diminish from about 70° to 50°. Beyond the Yellow Spring Gap the inclinations of both sets of strata grow progressively less, until at the Big Flats, 6 miles from the termination of the mountain, the dip is but 30° to the N., and only 20° to the S.

All along the Sharp Mountain, even to the termination of the basin, the strata—more especially the coal-beds of the S. side—are to a considerable extent faulty or disturbed; but this is probably the result rather of the excessive internal sliding pressure produced upon them by the close folding of the thick and ponderous mass, than by a wrenching force connected with any great dislocation. It is worthy of note that throughout the entire length of this basin the strata along the central belt are in a broken or crushed condition, and any attempt to reach solid coal there has been unsuccessful. The close synclinal doubling together of the rocks has greatly bruised all the materials along the axis of the trough.

I shall now proceed to describe the coal-beds of this basin. These will be best illustrated by a series of Sections constructed from the details contained in the work of Mr R. C. Taylor, where the reader will find the originals, of which these are not strictly copies, but modifications intended to embody, with his measurements, my own conceptions of the structure of the basin.

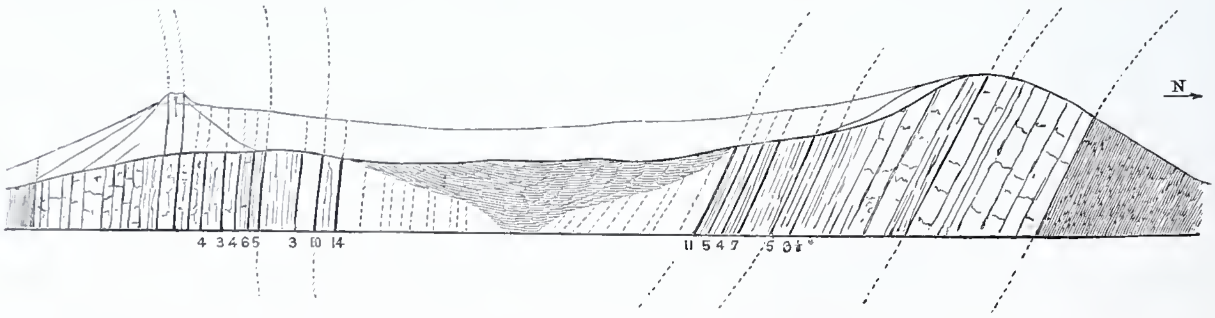


FIG. 181.—Section at Black Spring Gap, Dauphin Basin.

At *Black Spring Gap,* which is 26 miles from the Susquehanna, and 4½ miles from the Union Canal Reservoir, mining explorations have brought to light eight beds of coal in the S. belt, and six in the N. The dimensions, distances apart, and dips of these, are given in the accompanying Section.

The *Four-Feet Vein,* the most Southern one opened, is 170 feet N. of the vertical wall of conglomerate which here forms the crest of Sharp Mountain. It has a breast of 300 feet, has been occasionally mined, and is a pure free-burning anthracite.

The *Peacock Vein* is from 6 to 8½ feet thick at a shaft midway between Black Spring Gap and Mount Eagle, but is thinner at Mount Eagle. This coal contains 7 per cent of volatile matter.

The *Heister Vein,* 10½ feet thick, and with a breast 250 feet high, had, when seen, a drift in it 1000 feet long. One layer of this coal is excellent.

The Grey Vein.—This bed has been reported to contain about 14 feet of pure coal, and to have a total thickness of 16½ feet, but my own observations do not confirm this statement.

Iron Ore occurs in this group of strata, in the shales S. of the Peacock Coal, in three layers of balls.

At the Black Spring Gap the conglomerates of the Sharp Mountain and the included coals dip a little S. of the perpendicular.

In the centre of the basin there is a belt 2100 feet wide between the two sets of coal-beds, where no coal has been discovered; but wherever a shaft has been dug, there has been found a great depth of fragmentary matter, or superficial "wash."

On the N. side of the basin the several coals of the series opened are, according to Mr Taylor,—

The *Tunnel Vein,* 3½ feet thick.

The *Five-Feet Vein,* a good coal-bed 5 feet thick.

The *Lea Vein,* 7 feet of good coal, with an undermining.

The *Slaty Vein,* 4 feet.

The *Carey Vein,* 5 feet of soft and flaky coal; and the

Fishback Vein, 8 to 11 feet. This coal contains 9½ per cent of ashes, and 6½ per cent of volatile matter.

The coal-beds of this N. group dip S. at an angle of 70°.

My own personal inspection of this ground convinces me that the above-stated thicknesses are exaggerated.

At the Gold Mine Gap, 1½ miles W., the Peacock, Heister, and Grey Veins, and one or two more, have been proved and opened; but the next details I shall here present are those of

The Rausch Gap Section.—Five miles W. of Black Spring Gap is Rausch Gap, where the coal-beds have the positions and dimensions shown in the following Section (fig. 182).

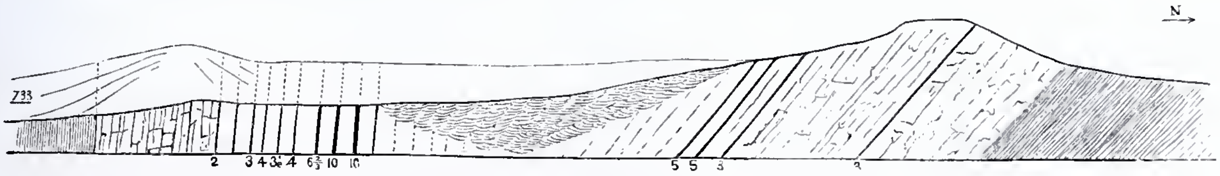


Fig. 182.—Section at Rausch Gap, Dauphin Basin.

There have been developed in the Southern belt at this locality ten independent seams, two of which are of important dimensions.

The *Heister Vein*, said to be 10 feet thick, contains 6 feet of good coal.

The *Grey Vein* measures 9½ feet of coal ; it has been driven into.

It is an interesting feature of the coals of this locality, that they are decidedly *bituminous*, displaying here the first distinct manifestation of a transition from semi-anthracites into the more adhesive or *dry coals* of the semi-bituminous class. We shall presently perceive that the proportion of bitumen gradually increases from this point Westward to the termination of the basin. Here the composition of the most Southern coal-bed of the Section, the Pitch Vein, is as follows :—

Carbon, ...	78.90 per cent.
Volatile Matter, ...	11.00 „
Ashes, ...	10.10 „

The analysis of the Heister Coal shows these proportions :—

Carbon, ...	73.10 per cent.
Volatile Matter, ...	10.90 „
Ashes, ...	12.00 „

The coal of the *Peacock Vein* burns with a yellow flame for a short time, denoting in it also the presence of bitumen.

Four beds have been opened on the N. side of the basin at this locality : one of them, on the summit of the mountain, is conceived to contain the best coal of the group ; they were not wrought far enough to fully develop them.

Yellow Spring Gap Section.—About 5 miles W. of Rausch Gap is that of Yellow Spring, where, in a series of exploratory shafts, Mr Taylor brought to light the facts exhibited in the following Section (fig. 183).

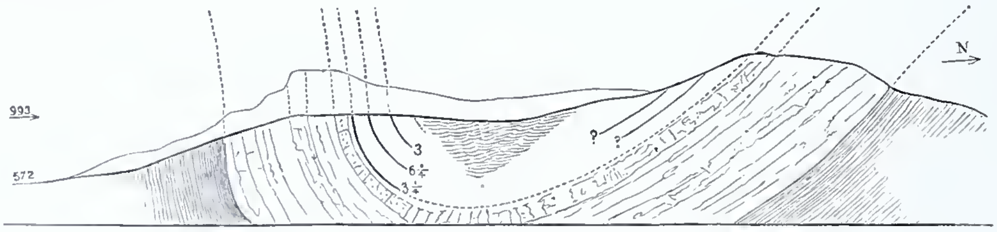


Fig. 183.—Section at Yellow Spring Gap, Dauphin Basin.

At this locality, 16 miles from the Susquehanna, the principal coal-beds outcrop at an elevation above the Pennsylvania Canal of 990 feet. There are here five separate beds discovered on the S. side of the basin, two of them only partially proved, the other three regularly opened within a transverse distance of 150 feet. One of these, lying immediately N. of the main bed of conglomerate, forming the *backbone* of the ridge, is called

The Backbone Vein.—It is 3½ feet thick, and yields 3 feet of good hard coal. This bed dips 85° N.

By analysis the coal contains, according to Lea,—

Carbon, ...	74.70 per cent.
Volatile Matter, ...	14.80 „
Ashes, ...	10.50 „

Our own analysis shows only about 10 per cent of volatile matter.

The *Kugler Vein* is about 6 feet thick, and dips 68° N. A drift has been cut in this bed

276 feet in length, and the coal was everywhere good. It burns with a pure flame, and contains,—

Carbon,	77.50 per cent.
Volatile Matter,	11.00 „
Ashes,	11.50 „

Another coal-bed is 3 feet thick. This dips only 37° N., and thereby possibly indicates that here the strata are bending to form a flat and shallow bottom to the basin.

About 60 feet N. of the last is another small coal, the size of which is unknown.

A fifth coal-bed outcrops to the *South* of the backbone of the mountain, but the thickness of this had not been proved.

On the N. side of the basin two or three coals are seen, but they have not been proved.

Neither of the large beds developed at Rausch Gap have been yet discovered at this locality, and it is questionable if they extend thus far towards the W.

Rattling Run Gap.—At this ravine, which is the deepest in the basin, and the nearest to the Susquehanna, the explorations by Mr Taylor brought to light a number of coal-beds, of which two or three are thick enough to be profitably wrought. Here have been disclosed sixteen (?) outcrops in the Sharp Mountain, twelve of which are on the *South* side of the belt of rock which generally forms the crest, and four are near the summit. Two other coals of valuable dimensions are on the N. slope. The N. side of the *basin* has developed two or three beds. The sixteen Sharp Mountain coals are all thin, varying from 1 foot to 3 feet in size, and, like the coal in the conglomerate generally, are not sound enough to prove profitable, and some of them do not merit the name of proper coal-seams. They have a dip at the surface of 70° N.

The following details will explain the composition of the basin at Rattling Run :—

1. The distance from the red shale to the lowest or the 2½-feet coal of Sharp Mountain is less than 170 feet, chiefly soft shale.
2. The next belt of strata, chiefly conglomerate, is 100 feet wide.
3. Slate and argillaceous sandstones 140 feet, embracing four thin beds of coal.
4. Argillaceous rocks, including two thin coals, 130 feet.
5. Hard conglomerate, 100 feet wide,—contains one small coal.
6. Argillaceous strata, 160 feet wide at the surface, with three coals.
7. Conglomerates and sandstones, with thin layers of slate, 300 feet.
8. Grits and argillaceous strata, chiefly the latter, 240 feet,—three coals.
9. Conglomerates and sandstone, with a few soft strata, 450 feet,—one coal.
10. Alternating grits and shales, 1000 feet. In this space is embraced the two best coal-beds of the tract. It also embraces the obscure and broken ground in the middle of the basin.
11. The strata of the Fourth Mountain, from the coal to the red shale on its N. slope, are about 2800 wide, with a dip of 46° S.

The entire breadth of the belt from red shale to red shale is 5590 feet.

A feature which deserves attention in this Section is the occurrence of so many thin coal-beds, and of so much soft argillaceous rock throughout the conglomerate, or, more strictly, the merging together of the lower Coal-measures and the Seral conglomerate, the division between which, adopted purely for convenience sake, we have seen all along to be arbitrary. The position which the crest of Sharp Mountain occupies in the formation depends manifestly on the place occupied by the hardest and most massive stratum of conglomerate, since this would most resist the wearing action of floods; therefore at this locality, where the inferior rocks are the softest, and include beds of coal, these have their outcrop to the South of the summit.

Of the coal-beds here discovered the most important is that called the *Perseverance Vein.* This had been mined in a drift 400 feet long, and consisted of two layers containing together 4½ feet of coal, showing symptoms of enlarging.

On the Fourth Mountain a bed was discovered measuring 3½ feet thick.

Big Flats.—The following Section (fig. 184) will explain the structure of the basin at the Big Flats, a table-land, 2 miles in length, about 6 miles from the end of the mountain, and 4½ W. of Rattling Run. At this portion of its course the middle of the basin has risen until it forms the summit of the one synclinal ridge caused by the approach of the two monoclinal barriers of the basin, and the denudation of the external softer strata.

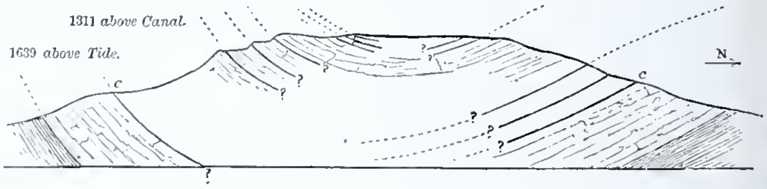


Fig. 184.—Section at Big Flats, Dauphin Basin.

Between the two outcrops of the red shale the width of the formation here is 2500 feet. The elevation of the plateau above the canal is 1327 feet. Near the very summit two or three beds of coal have been proved, and one of them ascertained by mining to be 2½ feet thick. These dip 18° N.

The following is an analysis of this coal by Professor J. C. Boott :—

Carbon, ...	71.20 per cent.
Volatile Matter, ...	15.32 ,,
Ashes, ...	13.46 ,,

Traced still farther Westward, we find the belt of coal strata to grow narrower and more shallow to the end of the mountain, the last 4 or 5 miles not having a breadth of more than 1000 feet. This tract includes of course only the very lowest portion of the series, or rather only the Seral conglomerate, with the few thin coal-beds embraced in its inferior beds. All the higher strata have been washed away.

CHAPTER XII.

MINE HILL BASIN, AND MINE HILL.

In order not to interrupt the continuity of description of the closely-united anticlinal and synclinal belts of the main Southern Coal-field, I have postponed the account of the Mine Hill Basin and Mine Hill to this place, though a more purely geographical arrangement would have introduced them in an earlier Chapter: indeed, they might have been discussed as prolongations of the Basin *C* of the foot of Locust Mountain, and of the anticlinal flexure C of the vicinity of Tuscarora; but this would have been to dissociate their Western tracts too much from the corresponding parts of the main basin.

It will assist us to a clearer apprehension of the somewhat irregular form of the Mine Hill Basin, if we first examine the structure of the anticlinal ridge S. of it, called the Mine Hill.

STRUCTURE OF MINE HILL.

In a former chapter the Southern anticlinal axis of the Eastern end of the coal-field, or that of the S. edge of the town of Tamaqua, was assumed as coincident with the main flexure of the Eastern point of Mine Hill. This view of their identity, though *proximately*, is not *strictly* correct; indeed, there is every reason to believe that the Sharp Mountain axis C is itself not strictly continuous as far W. as the village of Tuscarora; and there are still stronger grounds for regarding the South Tamaqua axis, traceable apparently to Tucker's Slope, as ranging considerably N. of the axis of Mine Hill, assuming this to be the flexure which passes just S. of the mouth of the Palmer Tunnel. The Mine Hill flexure, or group of flexures, is not only somewhat out of line with the Tamaqua one, but it is out of direction with it, bearing considerably more N. as it ranges W.

Mine Hill may be best described in two divisions, an Eastern and a Western, separated by Mill Creek. The Eastern, extending from Big Creek to Mill Creek, is a broad and nearly straight ridge, with a somewhat flat summit—a Southern wing, as it were, of the plateau of Broad Mountain. The Western Section, embraced between Mill Creek and West-West Branch, is a straight and narrow ridge, with a somewhat sharp crest and comparatively steep flanks. Eastern Mine Hill is partially divided from Broad Mountain by Big Creek on the East, and by Upper Wolf Creek on the West; but the watershed between these streams is very high, the indentation hardly there insulating Mine Hill from Broad Mountain. Silver Creek crosses this high valley Southward, and an extensive reservoir of its waters has been constructed at its passage across the high valley by the erection of an extensive dam of rude masonry; this reservoir is for the supply of water to the Schuylkill navigation during the droughts of summer. The elevated shallow valley occupied by Big Creek, by Upper Big Creek, the Silver Creek Pond, and Upper Wolf Creek, is an almost continuous shallow coal-basin, for coal has been opened not only on both sides of Big Creek, high towards its source, but also at the Silver Creek reservoir, and again at sundry points W. of the Broad Mountain Road, in the valley of Upper Wolf Creek.

Eastern Mine Hill, thus insulated from the Broad Mountain, seems to embrace in its central portion, or that intersected by Silver Creek, as many as three anticlinal flexures: the most Northern of these is the axis which, just S. of the mouth of Upper Wolf Creek, separates the Coal-measures of that basin from those of the colliery at the head of Mine Hill Valley, long known as Lawton's; it is confined to the N. brow of Mine Hill, overlooking Wolf Creek. It is an acute flexure at Mill Creek; but whether it extends as far E. as Silver Creek, is still, we believe, uncertain.

The central or main axis of the ridge is that which is visible on both sides of Mill Creek, in a noble arch of the conglomerate and lower White-Ash Coal-measures. The span of this arch or wave, measured from the synclinal turn of Lawton's Big Coal to the first N. dip in the same coal at the foot of Johns' Slope, is about 3400 feet; it is a fine example of a flexure of the regular normal type, the S. dips increasing as we approach the axis from 30° to 40°, and then abating, until the strata flatten at the crest of the wave, where the N. dips commence to augment rapidly in steepness, becoming soon as high as 60°, and even 70 , as we approach the N. foot of the wave. At this intersection of the flexure, three beds of coal are met with on both sides of the anticlinal axis; between the conglomerate and the Lower Big Seam, one of them is steadily wrought on the S. slope, and two of them have been opened for mining on the N. dip, but were, from the abruptness of the flexure, found too faulty to be pursued.

The basin, or the synclinal flexure between this central axis and the Northern one adjoining Upper Wolf Creek, rises so rapidly to the Eastward of Mill Creek that these three lower coal-seams are not likely to range far along the Mountain in that direction. The Big Coal of the Mine Hill Basin (Lawton's), conforming to this rise of the synclinal axis, does not enter the face of Mine Hill, but terminates with a spoon-shaped outcrop just W. of Mill Creek. It is difficult to say whether this central axis of Mine Hill is or is not the same with that which passes Eastward through the point of the ridge at Big Creek, and courses thence across Swift's Creek, and past the mouth of Palmer's Tunnel to Tuscarora. As forming the main crest of the ridge, they may be viewed as its central axis throughout, even though not strictly continuous. It is quite probable that, like the axis C, nearly in line with it farther E., it is made up of shorter flexures ranged in echelon. As the main conglomerate mass underlying the productive Coal-measures outcrops upon the line of this axis, high on the Eastern slope or point of Mine Hill, it is obvious that the workable beds of Big Creek do not ascend the Mountain very far, but fork into two lines of outcrop, the South-dipping one taking a course already traced, along the S. slope of the ridge to Silver Creek, the steeper North-dipping one a parallel course in the N. slope of the ridge towards the Silver Creek dam.

The third or most Southern anticlinal flexure of this division of Mine Hill is the axis D of its S. crest, or the partially-detached spur which I have entitled South Mine Hill. This flexure has been already traced from the Lower Whitfield Tunnel on De Long Creek, past the White-Ash Slope Mine of Casca William, and through Guiterman's Seam of Silver Creek to the S. arch of Mine Hill at Pinkerton's Colliery on Mill Creek. E. of Silver Creek, the anticlinal ridge marking this axis is insulated from the main body of Mine Hill by a high narrow valley containing the lower White-Ash Coal-measures, including the Big Seam; and W. of Silver Creek, the same anticlinal flexure forms a wider and longer spur, which is separated in a somewhat similar manner from the main summit of Mine Hill by the synclinal valley of Lower Wolf Creek, or the trough which embraces the N. outcrop of Johns' Big Seam of Mill Creek. The synclinal structure of this last-named valley is plainly manifested in the features of the district, and has been fully demonstrated by our observations on the dip of the strata, including the openings in the coal-beds. I am not sure that the E. point of the basin of Johns' Great Coal-bed within this valley has yet been ascertained, but it is probably between 2 and 3 miles E. of Mill Creek.

WESTERN MINE HILL.

In point of structure and topography, the other division of Mine Hill, or that lying W. of Mill Creek, is much simpler than the Eastern, just described: it would seem to contain but one principal flexure of the strata, and this a wave of the true normal type, moderately gentle in the inclination of its S. flank, and steep in that of its N. We have seen that at Mill Creek the steepest S. dip of the wave was about 40°, and the steepest N. dip 75°, and very nearly similar are the slopes of the curve at the passage of the West Branch, where the ridge, intersected to its base, exposes another grand arch of the conglomerate and lower Coal-measures. From Mill Creek to the West Branch, or the Mine Hill Gap, as it is called, and all the way, indeed, to West-West Branch, this undulation appears to decline steadily in width and steepness: thus at Mill Creek the Seral conglomerate rises almost to the summit of the ridge, and the breadth of its arch between the two outcrops of the lowest coal is not less than 2100 feet; whereas at the passage of the West Branch, though the hill is lower, the conglomerate is arched by the lowest Coal-measures under the summit, and measures from abutment to abutment not more than 1650 feet. Approaching the West-West Branch, the flexure grows very flat, and opposite the mouth of Buck Run it is probable that even its N. dips hardly exceed 20°. Whether this flexure contains but a single anticlinal axis, or is a little complex at its crest, is not quite certain. I am inclined to believe that it embraces two axes, or is, in fact, a double flexure at its summit a little W. of the Centre Turnpike. The breadth of this part of the ridge, and the bold shoulder which it throws forward towards Mine Hill Valley west of Newcastle, imply that two anticlinal axes may here lap past each other, and produce between them a narrow and shallow synclinal trough, which may even contain one or two of the lower coal-beds of the Mine Hill Valley, lifted obliquely into the mountain, as a species of short Southern spur from that basin.

It is obvious, from the foregoing description of Mine Hill, that no productive Coal-measures, except in the several localities we have alluded to, are likely to be found along the top, or even high on the slopes of this ridge, either in its Eastern or Western sections.

MINE HILL BASIN, ITS STRUCTURE, COAL-SEAMS, AND COLLIERIES.

The Mine Hill Basin, taking the name in its largest sense, is the complex trough of Coal-measures included between the main anticlinal crest of Mine Hill, and the S. brow or slope of the Broad Mountain. All the central part of the belt, or that embraced between Newcastle and Heckscherville, is a nearly simple synclinal trough of a normal curvature of the strata—that is to say, the North-dipping Coal-measures S. of its main synclinal axis, in the flank and at the foot of Mine Hill, dip steeply to the N., while those to the N. of that line, at the foot and in the slope of Broad Mountain, dip S. at a more moderate angle. Towards both of its extremities, however, this basin forks or subdivides into two branches. Of these bifurcations the Western is the most symmetrical. The subdividing of the Eastern end of the belt is occasioned by the presence there of a narrow steep anticlinal wave, which, prolonged Westward from the N. brow of East Mine Hill, crosses Mill Creek just S. of the mouth of Upper Wolf Creek, and ranges along the S. slope of Broad Mountain, almost directly in a line, to meet the anticlinal axis of the Peaked Mountain. This axis is traceable continuously from Mill Creek to the ravine of Butcher Creek; how much further it extends is uncertain. It appears to originate near the foot of Broad Mountain east of Coal Castle, and to make a sharp flexure in the lower White-Ash Coal-measures, rising gradually as it advances Eastward, until, at Kelly's Hollow and the mouth of Wolf Creek, it insulates a narrow sharp basin or **V** of the big lower coal-seam between itself and the main S. slope or brow of Broad Mountain. This narrow and pinched basin prolongs itself into the synclinal trough of Upper Wolf Creek, and thence through the Silver Creek reservoir to the head of Big Creek. Whether any of the Big Coal remains E. of Mill Creek, or in the part of the trough occupied by Wolf Creek, appeared, at the time of our observations, to be extremely doubtful. As a slender synclinal fold this narrow strip of the Coal-measures may be viewed either as a Northern branch of the Mine Hill Basin prolonged beyond the main Southern division, or as a Westward extension of the basin of Upper Big Creek, contracted and pinched towards its Western termination. Our Section of strata on Mill Creek exhibits clearly the relations of this narrow compressed synclinal belt at that ravine, to the broader basin S. of it. The pictorial sketch of Montelius's Open Mine in the Big Coal bed at the synclinal axis, illustrates the sharpness with which the Coal-measures, conglomerates and all, are here folded.

It has been already intimated that the main Mine Hill Basin ends in the table-land of Mine Hill, at no great distance E. of Mill Creek, the Upper or Big Coal not extending beyond the stream.

The W. forking of the basin is caused by the rising of an anticlinal axis, which originates somewhere E. of Heckscherville, or is possibly a prolongation of that S. of Upper Wolf Creek, rising Westward, and becoming the anticlinal of Peaked Mountain. This axis produces, with Mine Hill and Broad Mountain, two branch basins—shallow, symmetrical, synclinal valleys—which rise Westward into the table-land at the head-waters of the main Swatara.

The more Northern of these sub-basins, watered towards its W. end by the head-stream of the West-West Branch, is considerably the longest. The other or S. one, drained by the rivulet called Buck Run, reaches across the West Branch into the S. slope of Buck Ridge.

All along the N. side of the Mine Hill Basin, the outcrops of the several thick coal-seams of the lower White-Ash group, with their adjoining soft shales, are plainly indicated on the slope of Broad Mountain in a succession of soft indentations or vague terraces, which wind in and out at nearly constant levels, dimly seen in the ravines, but prominent enough on the buttresses or the spurs between them.

Having thus defined the general structure of the belt, I shall now proceed to offer some details concerning the more important collieries and coal-beds.

COLLIERIES AND COALS OF MINE HILL VALLEY.

Lawton's Old Colliery Gap.—This mine is seated in the E. end of the basin.

The coal of the Jugular or lower thick seam of the valley is wrought from a slope descending Westward.

On the S. dip the air-holes ranged W. for 900 yards.

At the date of our last visit the Slope was down 185 yards. On the N. dip the gangway continues all the way into Newcastle at the turnpike road. The dip on the N. gangway is about 60° S., and on the opposite or Mine Hill side of the basin it is 45° N. Under Newcastle, at the lower lifts, the two gangways are about 200 yards apart.

The average thickness of the coal is about 18 feet on the S. side, and from 15 to 16 feet on the N. Above this large bed is the so-called Seven-feet Coal, separated from the main mass by about 4 feet of slate.

The benches or layers in the Big Coal are—1. A bottom bench 6 feet thick, then 15 inches of bony coal and slate ; 2. A 15-inch bench with smooth parting slate, and 6 inches of bony coal ; 3. A 2-feet bench, with smooth parting layer of slate ; 4. A 4-feet bench, with smooth parting of slate ; 5. A 3-feet bench, with about 8 inches of bony coal. Then 4 feet of black roof-slate to the Seven-feet Coal.

The miners were driving a tunnel Southward from the S. gangway, to cut an overlying seam, which is 11 feet thick. The tunnel was only begun, and is in the Seven-feet Coal. They expected to pass in the tunnel 6 yards of actual thickness of slates, and above this a conglomerate. The coal here looked for is that which was mined further W. in the valley, but there is no positive proof of the presence of this 11-feet seam. This thick coal of Lawton's Old Colliery is manifestly identical with that of Fogarty and Kelly's Mine between Mill Creek and Newcastle, and that of Montelius's old open cut.

A tunnel about 200 yards W. of the bottom of the Slope has fully established this point, though the correspondence of the rocks on both sides of the anticlinal axis should have established it long ago. The dip of the measures at the Slope, and of the Slope itself, is 23° N. 20° W.

On measuring by strides from the outcrop of the Pea and Nut-conglomerate below the colliery to the line of the S. outcrop of the Big Coal, we found the distance to be about 250 feet. This corresponds pretty nearly with the distance measured in Adams's Tunnel. This ledge of conglomerate marks at Adams's the second bench, or, on a flatter dip, the third bench above the Egg-conglomerate.

BIG COAL OF KELLY'S HOLLOW.

After many explorations and a long period of uncertainty, the structure and contents of the narrow lateral basin of the slope of Broad Mountain, in the prolongation in the trough of Upper Wolf Creek, may be regarded as settled. It is, as I have already described it, a closely-compressed slender synclinal trough of the lower Big White-Ash seam, or so-called Jugular Vein, of the Mine Hill Valley. For a long time it was believed that the coal opened to the day opposite the mouth of Wolf Creek was the Mammoth bed, and that another large coal lay underneath this or the synclinal axis, and that it corresponded to the large coal of Johns' colliery. The succession of the strata, as may be seen in our Section, early convinced me of the improbability of this statement; and actual explorations by mining have subsequently confirmed the accuracy of the inference, by showing the supposed subjacent coal to be merely the slender point of the **V** prolonged downward in the plane of the synclinal axis.

At Kelly's Hollow the same thick coal had, at the period of our examinations, been somewhat extensively wrought by Fogarty and Kelly, and is now being mined by other parties. The openings and drifts occur on both sides of both Kelly's Hollow and the ravine W. of Newcastle, the E. side of which is climbed by the Centre turnpike; indeed, the upper levels have been wrought through to some distance beyond this ravine, the furthest air-shaft being now nearly 1000 yards W. of it. The workings are chiefly on the South-dipping coal of the narrow basin, where enormous cavities in the surface along the bench of Broad Mountain, which marks the outcrop, display the thickness of the coal, and the extent to which its roof has fallen in. The dip of this N. side of the basin is S. 30°; the coal has been mined by following the face of the bottom slate: near Kelly's Hollow the breast or slant height was 110 yards, and the thickness of the seam 30 feet. It consists of two main benches, a bottom one 8 feet thick, and a top bench 21½ feet thick, separated by a layer of slate varying in breadth from 4 to 10 inches. Overlying the thick bench is a bed of slate 2 or 3 feet thick, and above this a 3-feet-thick bed of coal, which burns to a pink ash.

At Kelly's Breaker we may see the outcrop of the Big Coal of Lawton's colliery, the S. face of the hill showing its bottom rock, and the sandstone and conglomerate beneath it; and the railroad ascending Kelly's Hollow cuts two coals in these lower measures, a 3-feet seam 60 feet below the Big Coal, and a 4-feet seam 120 feet below the same conspicuous landmark, all dipping gently S. from 10° to 20°.

MINE HILL VALLEY, FROM MINE HILL GAP WESTWARD.

Pine Knot Colliery (Adams and Miller).—At this colliery, near Coal Castle, there is a slope on the *Daniel* Coal. The distance down was 120 yards : the dip at the slope is 40° S.; Eastward it increases to 60°. The seam has a total thickness of 18 or 22 feet. At a fault to the E. of the workings it is only 4 feet thick. It has five benches—*a.* bottom bench, from 3 to 5 feet of clear pure coal; hard slate from 3 to 4 inches thick; *b.* 18 inches of good coal-parting; *c.* a 2-feet bench-parting; *d.* a 4-feet bench of bone and slate; *e.* an 18-inch bench-parting; *f.* from 18 inches to 2 feet of slaty roof.

Air-shafts extend Eastward about 1000 yards; they met a small fault at that distance. The outcrop of coal keeps the foot of Broad Mountain all the way. There is an opening on the seam a little W. of Newcastle, about 500 yards E. of Adams's last air-shaft.

Above this slope-coal occurs a seam, varying in thickness from 5 to 8 feet. The parting-slate at the Newcastle Mine (Lawton's) is regularly 4 feet thick. The top benches make a kind of pinkish ash.

On the second bench of the Broad Mountain, N. of that which bears the outcrop of Adams's Coal (the Daniel Vein), is a thick coal. This was struck in a tunnel driven from the tip of the slope Northwards about 100 yards, but not precisely at right angles to the strike. The dip in the tunnel is 40°. When struck, it was only about 5 feet thick, in a dirt-fault, but worked E. and W.; it was found to swell out into a coal from 20 to 25 feet thick. A large amount of coal was taken from it. The holes caused by the fall show a thick coal. An Egg and Pea-conglomerate evidently underlies the seam, as shown in the fallen outcrop. The dip of this Big Coal would be about 60°. It has been wrought about 800 yards E. from the tunnel.

Before reaching the Jugular, the miners cut a small 4-feet coal about half-way. It was thought that the tunnel does not reach the Jugular, but the *Tumbling* Coal. The tunnel cuts only one coal besides this, whereas there should be two between the Daniel and the Jugular. Upon this view, the outcrop visited behind Adams's is the *Tumbling* Coal. The interval between the Tumbling and Jugular at M^cGinnis's Mines is not more than 140 or 150 feet.

It is said that the Jugular bed can be traced from M^cGinnis's, by its bottom rock, to the air-holes at the Pine Knot Mine. This would seem to prove their identity.

I have been informed by those who drove and worked Adams's Tunnel, that Adams's Slope Coal is the true Daniel, and that the vein cut at the end of the tunnel is the Jugular. It has there the flaggy sandstone top, which may be readily recognised, and the bench and bottom rock can be followed from M^cGinnis's. The same measures are cut in Payne's Tunnel, but there are five coals between the Daniel and Jugular.

A coal-bed has been opened next N. of the Dutchmen's seam on Mill Creek, and in the bench next S. of the Egg-conglomerate. It contained 6 feet of hard bony coal. This would correspond to the coal opened on the Girard Road, on the N. dip, where it was 5 feet thick. The second bench W. of this is the place where, I think, the Johns' Coal lies, if it exist here. There is no seam known at this point, but a good mass of black dirt and slate. Below, or S. of it, is a dark-grey sandstone, much marked with vegetable impressions, passing at its base into a ledge of Nut-conglomerate. Above is a dark-grey sandstone, intermixed with Pea-conglomerate, like the rock of the small arch at Johns'. Between this last rock and the Southern outcrop of the Lawton Coal is a coal-seam 4 feet thick. It will be seen that in all these particulars there is a correspondence between the three seams in Adams's Tunnel—viz., Lawton's, the Small Coal, and the Big Coal; and the opposite side of Mine Hill, where we have Johns' Seam, Small 4 feet, and Pinkerton's.

Lewis Dougherty's Colliery, E. Side of Mine Hill Gap.—This mine is in the Daniel Seam, the N. dip of which is from 16 to 20 feet thick. The lower bench gives rather a *pinkish* ash. There is a coal from 7 to 9 feet thick about 7 yards above Dougherty's Big Coal.

The Jugular Coal in Mine Hill Valley burns to a *powdery white ash,* except the *lower* bench, which is a fine pink ash. The dip of Doherty's large vein is from 65° to 70° N.

Charles Hill's Colliery, W. of Mine Hill Gap—Tunnel and Boring.—The first coal cut in Hill's Tunnel is the Daniel, which is 12 feet thick, and in three benches; then 22 yards of hard rock and sandstone, to a coal 5 feet thick in three benches at the end of the tunnel. S. of the tunnel we have 15 yards of slate to a coal 3 feet thick—shafted; 2 feet of coal, the rest bony: then 25 yards of conglomerate and hard sandstone, to a coal 9 feet thick, in three benches: then 16 yards of sandstone to coal 6 feet thick, in three benches; and 25 yards to a coal 8 feet thick, in three benches. This last coal has over it a peculiar fine-grained flaggy sandstone, which we think is the overlying rock of the Jugular. Hill's boring on the top of Mine Hill was undertaken for the Jugular coal; it was down 100 feet, and had cut no coal. The probability is that it started beneath the Jugular Seam. The flaggy sandstone arches to the E. of the bony coal; but at the boring it is cut away, and with it, we suppose, the coal-bed.

M^cGINNIS'S HOLLOW.

A careful examination of M^cGinnis's Hollow proves that there is no anticlinal passing there. All the dips, from the conglomerate to M^cGinnis's Breaker, are S., except a little turn, not seen but inferred, in the position of the Tumbling Coal. (See Section at M^cGinnis's Hollow.)

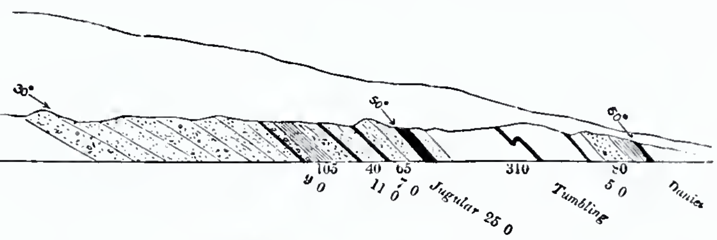


Fig. 185.—Section at M^cGinnis's Colliery, Coal Castle, looking E.
1 *inch* = 400 *feet.*

Commencing with the Egg-conglomerate, we have a series of coarse sandstones, forming four small ribs, a little conglomeritic. This covers about 100 yards, at an average dip of 30°. We then come upon a coal 9 feet thick, overlaid by a thick mass of conglomeritic sandstone and Nut-conglomerate. The coal-slate is seen directly in contact with the under surface of the rock, which is in sheets from 6 inches to 2 feet in thickness, and weathers grey. The sandstone and conglomerate are about 15 feet (?) thick. The argillaceous and sandy shales, exposed in some shafts, are about 30 feet thick, followed by a ledge of coarse Nut-conglomerate, with sandstone about 50 feet thick. Here comes in a coal-seam 11 feet thick, overlaid directly by dark-grey close-grained sandstone, and above this Pea-conglomerate. This space of about 40 feet brings in the coal 7 feet thick, over which is a heavy ledge of conglomeritic sandstone and Nut-conglomerate, forming a prominent rib some 25 feet thick. This supports the Jugular Coal.

Between the massive conglomeritic sandstone, below the Jugular and that coal, is a mass of coarse sandstone and slate, from 30 to 40 feet in thickness.

Over the Jugular is a coarse dark-grey sandstone and slate, which includes the Tumbling and the Iron coals, which are not marked by any decided ledge, but crop out in the same bench, lying between the top stone of the Jugular and the coarse sandstone and Nut-conglomerate, which occurs some distance below the Mammoth or Daniel Coal. This bed of conglomerate marks the

Southernmost bench, and crops out a little N. from the Breaker. It consists of pebbly sandstone, including irregular layers and nests of Nut-conglomerate in the lower part, and dark-grey sandstone and sandy slates above. The thickness here exposed is about 30 feet. It contains in the upper part many fossil impressions. The distance from the outcrop of the Jugular Coal to that of the Mammoth, along the railroad, is 390 feet, at an average dip of 50°.

Coals at McGinnis's:—

1. The Lelar Coal, 7 feet thick, was wrought here formerly.
2. The Mammoth or Daniel Coal is not wrought on the E. side of the ravine, but is on the W. Its average thickness is from 18 to 28 feet, in two benches; the lower from 4 to 8 feet thick; then 5 feet of slate, variable; then from 18 to 20 feet of coal, sometimes with slate-partings. Dip 35° S.
3. The Five-feet or Iron Coal is not wrought by McGinnis, being faulty.
4. The Tumbling Coal very variable in some places. The good coal is 20 feet thick; but it is generally dirt, not worth working.
5. The Jugular Coal averages from 40 to 60 feet, sometimes of solid coal, and sometimes in several indistinct benches. When distinct, the lower bench is from 6 to 8 feet thick, separating slates only a few inches; the remainder is all coal, with thin slate-partings. The dip of the Jugular is about 45°, becoming less ascending from the road-level to the outcrop. The breast from the road-level to the outcrop is about 120 yards. None of these veins have been wrought below water-level. The Daniel Coal has been mined under water-level as far as McGinnis's Drift Mouth on the W. side of the ravine. The Jugular Coal has been worked E. of the ravine about 175 yards, in a line with the openings on the Jugular at Adams's. It has been wrought W. to the next colliery (Sando's).
6. North of the Jugular is a coal 7 feet thick; 20 yards distant it was not wrought here.
7. North of No. 6 is a coal 11 feet thick; not wrought here.
8. North of this is a coal supposed to be 9 feet thick, but not wrought here.

DYER'S RUN, SANDO'S COLLIERY, ABOUT ONE MILE WEST OF McGINNIS'S.

The Jugular Coal has been worked out above water-level entirely through from this to McGinnis's. The pillars have since been on fire, and the place of this coal is marked by a band of burnt ground on the slope of the Mountain on the E. side of the hollow at Sando's. The colliery is on the W. side of the hollow. The direction of the outcrop of the coal from Sando's Mine shows it to be on the Jugular.

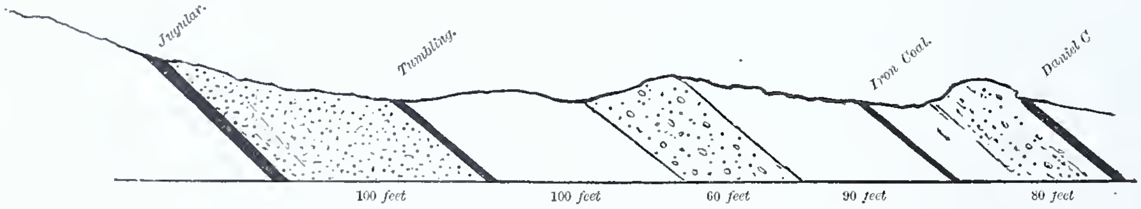


Fig. 186.—Dyer's Run, Sando's Colliery, about one mile W. of McGinnis's.

Sando's Coal is from 12 to 14 feet thick, with a dip from 45° to 35°, diminishing as we proceed. The work is only begun of late. Its breast farthest in is about 140 feet. The hill here on the S. side of Broad Mountain is lower than to the E., and is covered with debris.

The Tumbling Coal has been opened at McGinnis's, and found to form a kind of saddle or roll on the dip. Is not this the expiring effect of the saddle of the mouth of Wolf Creek, here dying out?

Sando enumerates the coals above the Daniel as follows: The Lelar, Crosby, or Knotwell coals, the Quaker Coal, Willkittie Coal. The Lelar Coal is from 9 to 11 feet thick; the Crosby, 7 feet; and the Willkittie Coal from 7 to 9 feet.

HECKSCHERVILLE SLOPE AND TUNNEL.

COALS.—The *Church* Coal had not been exposed, but was probably 11 feet thick.

The *Crosby* Coal gangway is below water-level; it was driven W. half a mile, and a quarter of a mile E. The thickness of the coal was from 11 to 15 feet, in three benches; the lower one from 4 to 6 feet thick, then a soft undermining about 3 feet; the middle bench 2 feet thick, with a thin parting of bone; the top bench from 11 to 15 feet thick.

The Lelar Coal.—There is a slope on this vein down 86 yards; the gangways ran W. 400 yards, and somewhat short of a quarter of a mile E. The average thickness of coal is 6 feet, in two benches about equal, and separated by 2 inches of slate.

The Daniel Coal.—At the water-level the gangway on this bed runs $1\frac{1}{2}$ miles W., and a quarter of a mile E. The breast is 450 feet above water-level; its average thickness is from 20 to 25 feet, in three benches. The bottom 6 feet of pure coal, then 9 inches bone, and from 2 to 3 feet of inferior coal. The middle bench is from 6 to 7 feet thick, then about 6 inches of bony coal, and an upper bench from 4 to 6 feet.

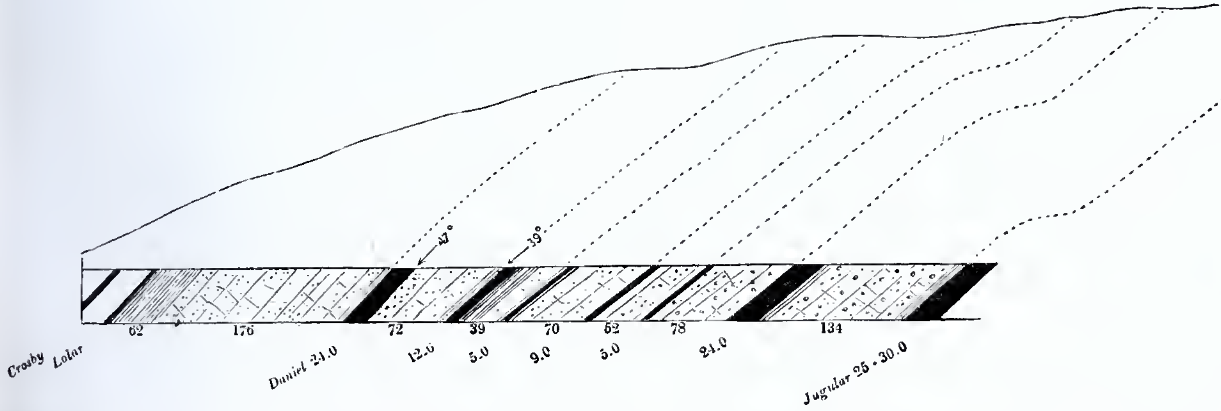
The Daniel Coal is certainly traceable W. to the next colliery (Mecke's) by air-shafts, and from thence by workings on to Staunton's at Glen Carbon.

The coal next N. of the Daniel has been worked by a gangway at the water-level; it was about 3 feet thick; from slate to slate 11 feet.

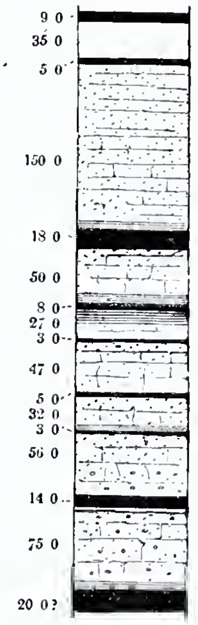
The *Jugular* Coal was worked above water-level by drift; the gangway was driven W. half a mile, and E. a quarter of a mile, or a little over. The breast at its highest point was 600 feet. The average thickness was 30 feet; it sometimes reaches 50 feet in thickness.

BENCHES.—The top bench is about 5 feet thick; the second about 2 feet of bony coal; the third about 3 feet thick; the fourth has about 3 feet of bony coal; the fifth about 4 feet of good coal, and 4 inches sandrock; the sixth has 5 feet of shelly coal; the seventh has 6 feet of coal.

FIG. 187.—Heckscherville Tunnel, looking E.—1 *inch* = 200 *feet.*



Strata cut in Heckscherville Tunnel.
1 *inch* = 200 *feet.*



The Jugular and Tumbling Coals are both affected by a flexure; this is no doubt the dying-out of the anticlinal seen towards the E.

THOMASTOWN TUNNEL.

This is a quarter of a mile W. of Payne's Tunnel, on the S. side of the basin. It has been driven S. 180 yards, and cuts only *one* coal 7 feet thick, dipping N. 37°. It was supposed by some to be the same coal cut in Oliver's Tunnel in Peaked Mountain. The distance between the outcrop of the Crosby Coal of Payne's Tunnel and the North-dipping coal of Thomastown Tunnel is 700 yards. The Thomastown Tunnel is 1370 feet S. of the creek, and about half-way up Mine Hill.

OLIVER'S COLLIERY, PEAKED MOUNTAIN.

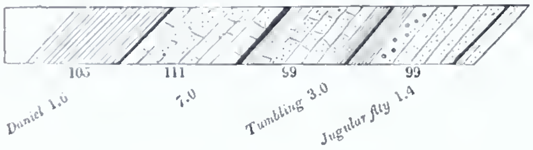
A tunnel here was driven S. into Peaked Mountain. It is a double-track tunnel, which cuts two coals. The first is 10 feet thick, and the Back Vein is 16 feet thick. The Back Coal is probably the Big South Coal of Staunton's Tunnel and the Crosby of Payne, as the following considerations imply:—

It is 94 yards in Staunton's Tunnel, between the Daniel and the Big South Coal. The Superintendent at Oliver's says he has shafted on Peaked Mountain, and found coal 7 feet thick at about the same distance behind the Tunnel Back Coal. It has a fine sandstone top corresponding with the Daniel Coal. He has also shafted 3 feet of dirt-coal about midway between the Back Coal and the supposed Daniel Coal, corresponding with what is seen in Staunton's. The dip of the Back Coal in Oliver's Tunnel is 50° N.; the dip of a coal 10 feet thick is 52°; the dip at the mouth is 54°. The gangways on the Back Coal run E. 175 yards, and W. 900 or 1000 yards. On the bed, 10 feet thick, the gangway runs 30 yards E. and 100 W. There is thin conglomerate between the 10 feet of coal and the Back Coal, composed of nut and pea-sized pebbles.

MECKESBURG—MECKE'S WESTERN TUNNEL.

This tunnel starts N. of the *Crosby* Coal, and cuts about 20 yards to the outcrop of the *Daniel*, then 25 yards to the 7 feet of coal of Staunton's Tunnel, 37 yards 2 feet to a small bed 3 feet thick, 50 yards to the Tumbling Coal, and still Northward about 30 yards to the Jugular. The dip is about 45° S. throughout: then from 25 to 30 yards to the coal beyond the Jugular, in the Eastern Tunnel, to coal 5 feet thick, 3 feet of which is good coal.

FIG. 188.—Mecke's Tunnel, Meckesburg, looking E.
1 *inch* = 200 *feet*.



The thickness of the *Daniel* Coal is from 6 to 7 feet. In the tunnel it was only 2 feet thick, but a gangway was driven W. about 350 yards, and at 60 yards the bed was of its regular size. The next or 7-feet coal is the same as in Staunton's gangway W. 400 yards.

The *Tumbling* Coal varies from 2 to 10 feet in thickness; it had no gangways driven.

The *Jugular* Coal is from 4 to 20 feet thick, its average thickness being 18 feet: it is sometimes faulty; the fault runs N. and S., and affects all the coals on Mecke's property. A gangway was driven only a short distance.

A 5-feet coal was not reached in the Western Tunnel. In the Eastern Tunnel the gangway was driven 900 yards W.

The overlying rock of the Daniel Coal is a fine sandstone: over the Jugular Coal is a Nut-conglomerate and sandstone; and *under* the Crosby Coal is slate all the way to dirt-coal in Staunton's Tunnel, except a little shelly sandstone.

GLEN CARBON—STAUNTON'S TUNNEL—DUNDAS TRACT.

This tunnel is driven Northward 54 yards to a dirt-vein, averaging from 5 to 9 feet in thickness. The miners ran on this 54 yards Westward, and then tunneled N. and S.: 54 yards N. of the dirt-bed they cut the bottom slate of the Daniel Coal, which vein is 16 feet thick there, but is usually from 6 to 7 feet. Before reaching the Daniel Coal, two small leaders were cut, one 18 feet S., and the other about midway: the former is always over the Daniel Coal; its dip is about 45° S. from the Daniel bed: the tunnel runs 16 yards N., and cuts a 7-feet vein, with 3 feet of workable coal—the rest is bone coal.

Thirty-five yards S. from this dirt coal (thought to be Payne's Lelar or Slope Coal), a coal from 16 to 18 feet thick, said to be Payne's Crosby Coal, was tunneled and cut; dip 60°. (Is it not the Black Valley Coal and the Dirt Coal—the Black Heath Coal?) The distances here correspond well with those in Payne's Tunnel.

The gangways on the *Daniel* Coal were driven 1000 yards W., not E. at all. The Daniel Coal lies in four benches, with but one parting of slate; the rest is bone.

The gangway on the 7-feet Black Coal was driven W. from 350 to 400 yards. There are five benches, two of workable coal, the rest of bone.

On the *Crosby* Coal, the gangway was driven W. 900 yards. The coal usually lies in four benches, but sometimes in only three, with slate partings. The dips are more rapid in these gangways in going W. The coals are all *White Ash.*

ROHRERSVILLE—ROHRER'S MINES.

At this colliery six coals are opened in all. The 1st or lowest saddle is on the turnpike, or a little S. of the highest part of the ridge. It has 18 feet of good coal, 500 yards above water-level.

The 2d Coal crops out 70 yards S. of the outcrop of the 18 feet of coal; its thickness was not known; it is a rough hard coal.

The 3d is a coal one yard thick, soft and faulty. It is 50 or 60 yards S. of No. 2.

The 4th is the Roan Coal, 17 feet thick; it yields about two-thirds good coal, and has one yard of slate in it; dips 50° S. It is about 170 yards S. of the Saddle Coal, No. 1.

The 5th, from 12 to 15 yards S. of the Roan Coal, is 3 feet thick, and soft.

The 6th is 3 yards S. of No. 5, and is one yard thick; all S. dip. In a tunnel driving N. near the old sawmill they have cut four coals within a distance of 50 yards (1852).

PEAKED MOUNTAIN AND BUCK RIDGE ANTICLINAL, AND LIMIT OF COAL IN BUCK RIDGE BASINS NORTH AND SOUTH.

Proceeding to the end of Buck Ridge, on the S. slope, at Rohrer's Mines, we behold the upper Egg-conglomerate cropping out on a S. dip; crossing the end of the ridge Northwards, sandstone dips 12° S.; and continuing on, we come upon the N. dips of the same rocks on the N. flank of the ridge, which leads to the conclusion that the anticlinal axis occurs in the N. crest of Buck Ridge. Following this N. dip of the conglomerate Eastward to the creek, we find that it forms the N. dips of the W. end of Peaked Mountain, which may be followed along the axis to the turnpike. The axis seems flattened at the road. The Peaked Mountain axis of Rohrer's Mines appears to be but feebly felt at Oliver's.

From an examination of the rocks between Mine Hill and Buck Ridge, the conclusion arrived at was that the coal does not extend even so far W. as the head of Buck Run.

On the N. side of Buck Ridge we may see the upper Egg-conglomerate in the bed of the creek, and above this, sandstones dipping flatly to the N.E.; and farther on, other sandstones dipping S.E. 45°.

There is probably more coal in this basin further W. than in the basin S. of Buck Ridge.

BUCK RIDGE AND PEAKED MOUNTAIN ANTICLINAL.

This is the bold anticlinal which forms the high ridge N. of Mine Hill, merging from Mine Hill at a point as far W. as Swatara Creek, and very gradually sinking Eastward: it forms the important axis which, as far E. as Meckesburg, divides the Mine Hill Basin into that included between it and Broad Mountain, and the other between it and Mine Hill. At a point about three-fourths of a mile S.W. of Tobias's Mount Pleasant Tavern, the axis is arched by the great lower Egg-conglomerate, with N. and S. dips of about 30° each. Traced Eastward, it is found to be saddled by somewhat higher measures, and at the E. end of the so-called Buck Ridge we find the sandstones and smaller conglomerates which overlie the great upper Egg-conglomerate forming a conspicuous saddle. Here, however, the axis appears to occupy the N. brow of the ridge.

By a careful tracing of the N. dips of the great Egg-conglomerate, exposed at the E. end of Buck Ridge, across the swamp to the most Western end of Peaked Mountain, they are seen to correspond exactly with the North-dipping measures of Peaked Mountain; and although the course of Peaked Mountain is not at all that of Buck Ridge, the fact would seem to be clearly established that they are formed by the same great anticlinal which, as it declines suddenly, elbows more towards the S., and, arching higher and higher coals of the White-Ash series, seems finally to disappear entirely, in the topography of the country, about one-fourth of a mile S.E. of Meckesburg.

The exact position of the Peaked Mountain anticlinal is discernible on the turnpike road which crosses the ridge near the Rohrersville Colliery. It is almost at the flat low crest of the ridge, a little more than half a mile S.E. of the Mount Pleasant Tavern. Here the lowest of the Rohrersville coals makes a saddle across the axis: it is 18 feet in thickness. On the S. side of the anticlinal seven other coals have been opened, five of which, in the vicinity of the Rohrersville Colliery, prove to be of workable thickness, one of these, Raun Vein, being in all 17 feet thick, but containing of good coal only 3 or 4 feet. The dip of this bed is S. 50°. The remarkable deflection in the anticlinal of the Buck Ridge, to prolong itself as that of the Peaked Mountain, suggests naturally a somewhat different view of the structure of the ridge at this place of seeming dislocation, where the abrupt change in the trend of the ridge takes place. So great an elbow in an anticlinal can hardly exist without considerable twistings and warping of the strata, and is most apt to be connected with a doubling of the axis, producing one or more intermediate dislocated troughs or undulations; and such is possibly the case at this locality. This wrenching of the axis indicates, in other words, a lapping of one anticlinal point past another, a phenomenon displayed on a grand scale in some of the great axes of the Upper Juniata, in Huntingdon County. Considering the Buck Ridge and Peaked Mountain anticlinal as one, we may still, in accordance with this idea, adopt either of two notions respecting the manner in which it makes its elbow—either that the Buck Ridge axis prolongs itself N. of the Western end of the Peaked Mountain portion into the Northern Branch Basin;

or, what appears to be more probable, that the Peaked Mountain axis, extending Westward, passes to the N. of the Eastern end of the Buck Ridge portion. For a clearer understanding of this anticlinal, the reader will consult the Map. It becomes here an interesting question, how far Westward this Western point of Peaked Mountain axis may enter the Northern Branch Basin on the Hartman Tract. It is difficult to conceive that so marked an anticlinal can either expire so soon, or bend so suddenly, as not to produce some elevation of the strata towards the centre of that basin.

OF THE SOUTH-WESTERN BRANCH OF MINE HILL BASIN.

Of the coals which enter Westward from the main Mine Hill Basin, its Southern branch, or that embraced between the Mine Hill anticlinal and the Buck or Peaked Mountain axis, no very precise knowledge has yet, in the infancy of mining there, been attained. That the Daniel or Great Mammoth Coal, and those adjoining it, do not enter this subordinate basin far, but swing their outcrops Northward from the base of Mine Hill to the point of Peaked Mountain, and then inflect them Westward along the Southern side of the Northern Branch Basin, seems to be the prevailing conviction of those who are working these coals to the Eastward, and all who are best informed respecting the features and structure of the district. If such be really the state of things, it is obvious that none but the lowest White-Ash coals, or those between the horizon of the Jugular and the upper Egg-conglomerate, can have a place in this trough. It is pretty certain that no coal-seam—none, at least, of workable size—can extend as far as the head of this basin, which is only half a mile E. of the watershed of the Swatara Valley, for here the sandstone over the lower Egg-conglomerate, which is below any minable coal, itself forms the bed of the valley, and therefore the more available coals overlying the upper Egg-conglomerate can have no existence so far to the Westward.

The great White-Ash coals, the Mammoth and Jugular inclusive, enter this basin some distance Westward; the Jugular, however, grows thin and faulty even at Meckesburg, while the Daniel (Mammoth), Crosby, and contiguous coals, stretch on Westward on the N. side of the basin at the foot of Broad Mountain, beyond the Glen Carbon Colliery; but how far, has not been positively determined by actual mining further than some 1500 feet W. of the Glen Carbon Tunnel. The outcrop of the Daniel Coal has, however, been identified, it is believed, almost as far Westward as the forking of the turnpike near the Mount Pleasant Tavern. That this vein prolongs itself into the Hartman Tract, outcropping, however, not so near the margin of the valley, is quite probable; but the mining operations now commenced in this quarter will soon settle this locally-important question. The Crosby, a higher coal, cannot of course extend itself as far to the Westward as the underlying Mammoth Vein; while the Jugular, a lower but much more fluctuating coal, having its outcrops on the slopes of the ridges, will necessarily, if it exist at all as a traceable or workable seam, throw itself considerably further forward before it basins out in turn towards the head of the valley. All of these coals are of course to be found on the S. side of the basin at the foot or on the slope of the Peaked Mountain and Buck Ridge; but the coals there mined in Oliver's Peaked Mountain Tunnel have not thus far been positively identified, though an impression prevails among the experienced that Oliver's 16-feet Vein is the equivalent of the Crosby of the Broad Mountain side of the basin.

How far Westward any productive coals extend towards the head of this valley, present developments do not determine; but sandstones overlying the upper great Egg-conglomerate have been detected by us $1\frac{1}{3}$ miles S.W. of the Mount Pleasant Tavern. Thus far the lowest coal-seams may probably extend in a contracted synclinal point, and their furthest prolongation will be found, we suspect, along rather the S. side of the valley—a natural consequence of the greater steepness of the N. or Buck Ridge dips, over the S. dips at the foot of Broad Mountain. However, it must be observed, that W. of our Section, and a little N. of the stream at the foot of Buck Ridge, flattish dips to N.E. are seen in sandstone; while further Northward a few hundred feet, another sandstone plainly exposes a steeper dip of 45°, directed towards the S.E. This last-named high dip, taken in connection with the still steeper inclination of 50° S. in the newly-opened 12-feet coal of the N. side of the basin, some 400 yards W. of Mount Pleasant Tavern, is certainly an encouraging feature respecting the depth of the Coal-measures, and the amount of coal in this W. portion of this Northern Branch Basin.

The coals opened (down to the date of the autumn of 1852) on the Hartman Tract, on the N. side, with S. dips of from 45° to 50°, are,—

First in ascending order, a rough coal, 4 feet thick. This will probably yield not more than $2\frac{1}{2}$ or 3 feet of good coal.

Second, a good coal, 11 feet thick, dipping 50° S. This promises 9 feet thickness of good coal.

On the opposite or S. side of the basin three coals have been opened; they dip 80° N. The uppermost of these, all of which are more or less compressed and faulty, is squeezed at its outcrop to a thickness of 3 or 4 feet, but further down it is said to be 6 feet thick.

The next under it crops out Southward about 30 feet; and S. of this again, 20 feet further, rises another seam. I forbear to give their dimensions until they shall have been more thoroughly explored.

CHAPTER XIII.

DESCRIPTION OF THE MORE IMPORTANT COAL-SEAMS OF THE SOUTHERN COAL-FIELD, WITH THE DUPLICATE NAMES WHICH MANY OF THEM BEAR.

I HAVE devoted much pains, in the progress of the geological survey of the anthracite region, to noting and recording the characteristic features of the individual coal-seams, to tracing the variations of type which they undergo, to ascertaining their identity from section to section, and the double names which many of them possess. From the circumstance that, from the commencement of mining operations, in the S. basin especially, down to the present day, the chief collieries and explorations for coal have started in the valleys which intersect the basins, the identity of the beds, from valley to valley, remains even yet imperfectly known. In the absence of such knowledge of the equivalencies of the locally open beds, it was natural, indeed inevitable, that the miners should assign either local names, or apply the known names of distant coals erroneously, to their own favourite seams. A desire to apply to a newly-found coal, or a newly-organised mine, the name of some bed of established repute nearly in the same range with it, where a scrupulous tracing of their outcrops might have proved them dissimilar, has added not a little to the excessive confusion of nomenclature which now exists, to the serious detriment of the mining interests of the region.

Not a few of the disastrous disappointments which attend mining enterprise in the Pottsville Basin may be attributed to the prevailing ignorance of the true range and identity of its coal-beds, one main source of which, next to a want of clear tracing of the anticlinal and synclinal flexures, is the confusion in the naming of the coal-beds.

In the hope of repairing this lack of knowledge, I have annexed to this chapter on the individual coal-seams, some important notes upon the identity of the coals known under different names.

DESCRIPTION OF THE SEVERAL COALS.

Coal A of Tamaqua.—The bottom rock of Coal A at Tamaqua is a heavy Nut-conglomerate, with a breast of 700 feet, and dipping at the river about 65°. A tunnel is driven to it at Reinhardt's Run. The thickness of the entire bed at the river is 16 feet; it is not worked to the E., and nothing therefore is known of it in that direction; but to the W. the gangway extends in for about 350 yards. This coal appears to be all in one body, with no parting-slates, but a good deal fissured and rubbed.

Three coal-seams have been found N. of Coal A, but of these nothing is known to the W., while they are wrought to the E. at Nesquehoning; that behind A is probably the Nineteen-feet bed at Nesquehoning; the next is a 5-feet coal, and the lowest coal is 28 feet thick.

At Nesquehoning there are two other small veins of coal still further N., making in all five beds N. of Coal A, in that region. Only three beds have been discovered here, and these appear to be nipped or contracted at the outcrop.

Coal B of Tamaqua.—The E. side of this bed is not opened; the W. side dips about 65°, judging by the rocks. It crops out N. of the first ledge of conglomerates. The average thickness of this coal near the river is about 9 feet, but on the mountain it is more than 12 feet. It outcrops about half-way up the N. slope of the Locust Mountain. It is worked at the Newkirk Tunnel.

The coal-seam next North of D in Newkirk Tunnel (B or C of Tamaqua) has been driven 400 yards E. and 400 yards W. of the tunnel. This is strong Red-Ash coal. 200 yards W. of the tunnel there is an air-shaft, which is 287 yards up the breast; the air-shaft from the tunnel is 726 feet up the breast. 200 yards E. of the tunnel the air-shaft is 549 feet up the breast. The dips are severally 30°, 28°, and 42°. This coal-bed is faulty to the E., but good to the W.; its average thickness is about 17 feet.

Coal C of Tamaqua.—This bed is faulty on the E. side; its thickness on the river is 6 or 7 feet; on the W. side it is 8 or 9 feet thick, and it still thickens going W. Its dip at the river is from 55° to 58°. It has been driven in a W. direction about 900 feet.

This coal-seam exhibits, in an ascending order, clay-slate at the bottom, overlaid by 2 feet of good coal; then 6 inches of slate, above that 2 feet of good coal; next, 6 or 7 inches of slate; and then 3½ feet of coal, overlaid by slate.

Coal C, cut in Newkirk Tunnel, was there pinched down to 20 inches.

The bed North of Coal D in Newkirk Tunnel, already referred to, is no doubt the bed C of

Tamaqua, and not B, as was supposed. Ratcliffe's line of air-holes on D, west of Tamaqua, are extended to nearly opposite the end of Wigan's working in the disputed vein Eastward of Reinhardt's Run. The interval between the two ranges of outcrop is nearly the same as that between C and D at Tamaqua.

The Coal C at Tamaqua is underlaid by about 4 feet of slate, below which is a thin coal-seam not wrought. In the mine at Newkirk Tunnel, the slate-bed is reduced in thickness, and becomes a slaty coal; and the underlying coal, here 3 feet thick, is wrought with the rest. This bench yields a strong pink ash. It is interesting to ascertain whether the bench below the slate at Tamaqua would yield a coal of the same kind.

Coal D of Tamaqua.—This bed on the E. side has a thickness down in the slope of from 14 to 16 feet. It has been driven E. 1400 yards in the old upper level, where a rock-fault was approached which heaved the vein off to the S.E.

This bed displays on the top level, in an ascending order, hard clay-slate; then 3 feet of clean hard coal; next, 6 inches of slate; above this, 4½ or 5 feet of long-grained streaky coal; then 1 foot of rough bony coal, overlaid by 2 feet of slate.

At a depth of 385 feet below the top of the slope is found, in an ascending order—first, clay-slate; above that, 7 feet of clean hard coal; next, 6 inches of slate; over this, 8 feet of good coal; then 1 foot of rough coal; and on the top 2 feet of slate coal, with *Stigmaria* in the coal.

The dip at the bottom of the slope is 68°, at the top it is 56°.

On the W. side Coal D has been driven through to Reinhardt's Run on the top level. The coal is nearly the same on the top level as at the E. side, both in quality and thickness, but flattens in pitch. At Reinhardt's Run the dip is only 42°. The height of the breast is 280 feet from the upper level; when on the hill it is 420 feet.

Coal D has been cut in Newkirk Tunnel, and also in Greenwood Tunnel.

At Buckville Tunnel the next bed N. of Coal E has been worked W. about 170 yards. It is separated here from the Cross-cut by 10 feet of slate. They are here wrought together.

Coal E of Tamaqua.—This coal-seam has been driven through towards Reinhardt's Run to within 300 yards of the Reinhardt's Run gangway, or 600 yards from the tunnel, in which it is cut and found pinched. The breast on the last air-shaft of E is 420 feet. The dip is here about 55°, but at Reinhardt's Run 42°. It flattens very little towards the outcrop. Sometimes there are four or five benches on the E. side.

The coal-seam E of Tamaqua exhibits, in an ascending order—first, soft shale; then 4½ feet of clear hard coal; afterwards, 9 inches of slate; upon this, 12 feet of long-grained streaky coal; next, 12 or 15 inches of slate, overlaid by 3 feet of good coal; then 2½ or 3 feet of slate; and on the top, sandstone grit.

Towards the W. this seam runs rather faulty. On the E. it has been worked through to the Greenwood Tunnel, in which it is cut, and rates at about the same dimensions. At Reinhardt's Run it is reduced in dimensions. In Newkirk Tunnel it is found pinched, but to the E. it retains its thickness.

This coal-seam is now worked through from Tuscarora to Newkirk Tunnel. In the tunnel it is only 12 or 15 inches; it has been worked E. about 800 yards; at 400 yards, about 12 or 15 feet have been wrought; and at 600 yards, 30 feet have been worked. It then declines to 12 or 15 feet.

Coal E at Buckville has been worked E. from the tunnel 600 yards, and the same distance W. The thickness of the coal is about 18 feet. On the level, 300 yards E. of the tunnel, it is driven across to the "Cross-cut" seam.

In the Palmer Tunnel, a big seam, considered to be the same as E of Tamaqua, has been cut 97 yards N. of the Palmer. It has been driven 200 yards E., and about 125 yards W. The dip in the tunnel is 65°, E. of the tunnel it declines to 45°. W. of the tunnel it is unchanged. The average thickness is 20 feet, and the height of the breast 285 feet.

Cross-cut Coal of Tamaqua.—This bed is only 12 feet S. of Coal E, and at Reinhardt's Run it is 45 feet; it is probably the principal bed at Buckville. In Newkirk Tunnel it is 2½ feet thick, and in Greenwood 10 feet.

Sixty feet W. of Newkirk Tunnel it consists of 2 feet of hard glassy coal, capped by one foot of Bird-eye coal. It is largely wrought on account of its purity.

Coal F of Tamaqua.—This bed at the water-level is 90 feet lower than the same in Newkirk Tunnel. At Reinhardt's Run it dips 50° S., flattening towards the synclinal axis, the dip being 42° in the bottom of the slope, and 38° at the top. The seam is in two benches. The bottom bench is thickest on the E. side of the river, being 6 or 7 feet, while on the W. side it is 5 feet. The top bench is 7 or 8 feet thick on the E. side, and 6 feet on the W. side. It is cut in Greenwood Tunnel, and mined Eastward for about 1½ miles in the tunnel-level. A slope-mine enters into it at Carter's New Slope 3000 feet E. of G Tunnel, 500 feet down from the surface. The bed is there from 12 to 15 feet thick, and consists of Pinkish Grey and White-Ash coal. It dips 50° S. The 8-feet lower bench is Pink Ash. This appears to be the Eleven-feet Coal in Tunnel No. 8, or first above the large White-Ash seam on Panther Creek. It has been worked E. from Newkirk Tunnel one mile above the water-level. In the gangway, 450 lower, it has been worked E. 1800 feet. It has been worked W. from the tunnel, above the water-level, 600 yards, where a rock-fault comes in. In the level, 450 feet lower, the same fault was struck at 300 feet in working W. 300 feet have been driven in the fault.

It has been connected with Coal F at Tamaqua by a hole 60 feet deep from the end of Newkirk Level. The dimensions at the tunnel at Newkirk are 7 feet; 300 feet E. of the tunnel, 17 feet; and 600 feet further on, 22 feet. This continues to the end of the level, one mile.

The dimensions are—at the tunnel, 11 feet; 600 yards W. of the tunnel, 20 feet; then it is nipped. On a rise, 90 feet above the level, it is 40 feet thick, and faulty.

The bed called the Palmer Vein, cut by a tunnel driven N. from the Slope at Tucker's Slope, and cut in the Palmer Tunnel, is no doubt the F of Tamaqua. At Tucker's Slope it has been wrought about 4200 feet W. of Tamaqua, where it struck a rock-fault. It was driven E. about 800 yards, or within 75 feet of the line of Schuylkill County.

A slope has been put down on this bed, 285 feet E. of Tuscarora (Tucker's) East line. This is known to be the outcrop of the F Coal of Buckville, and therefore of Tamaqua. In the Palmer Tunnel this bed is from 12 to 14 feet thick. It has been driven on E. 600 feet to the line, and W. about 2400 feet to a fault, which appears to have heaved the bed towards the N. about 60 feet.

This bed is 138 feet S. of Coal F at Tamaqua, and is there 6 feet thick. It is cut in Newkirk Tunnel, is 3 or 4 feet thick, and in Greenwood Tunnel is 6 feet. In Buckville Tunnel it is 5 feet, and has a dip of 35° S.

Buckville.—Here the slope W. of the mouth of the tunnel is down 318 feet. The dip is 40° or 45° S., and the thickness from 10 to 12 feet.

A little more than half a mile E. of Tuscarora village is the coal of Tucker's Slope. It is 450 feet to the bottom of the slope, 270 feet below water-level. It has been driven 135 yards Eastward, and 1200 yards to the W. A remarkable dislocation was encountered at the end of the E. gangway.

Bowman's Slope on Reinhardt's Run displays in an ascending order—first, 5 feet of good coal, then 3 inches of coal-slate, next 4 feet of good coal a little faulty, overlaid by one foot of top clod.

Grier Coal of Tuscarora.—The bottom bench of this coal is Red Ash, and is 20 inches or 2 feet thick; the top bench is $3\frac{1}{2}$ feet thick, and is Grey-Ash coal.

This coal-bed is worked by a slope at the Newkirk Colliery on Reinhardt's Run, at a distance of 105 yards S. of Coal F in the tunnel there. At Reinhardt's Run it is called Bowman's Big Coal. Here it is a Pink-Ash coal, its regular thickness being 9 feet. 100 yards E. of the tunnel there is a fault in the rock. In this distance it varies from 9 to 40 feet in thickness. The dip at the slope on Reinhardt's Run is 40° S.

Tuscarora Coal of Tuscarora, supposed to be the Palmer.—This coal is said to be in two benches: the lowest, 4 feet of Red Ash overlaid by 4 inches of slate; the upper, 7 feet of Grey Ash, with a roof of fireclay.

Big Coal, or Mammoth Coal.—This cut is in Whitfield's Upper Tunnel, on De Long Tract; the average thickness there is 8 feet, being sometimes 11 feet, and often only 6 feet; it consists of three benches, and slate between the upper and middle benches: the top bench is sometimes rough, but the bottom one always pure. In these features this bed resembles that at Big Creek. The length of the gangways to the E. is 1200 feet; to the W. it is 3000 feet; the coal is faulty, and is from 10 to 20 feet thick.

At Casca William this coal-bed is about 18 feet thick, and has an average dip of 61° in the slope. The gangway on the lower level has been driven about 3000 feet Westward, and chiefly from the slope.

At Silver Creek the Big North Coal is the same as the Big Coal of Casca William. This is proved by the line of air-shafts which correspond.

Black Heath Coal.—At Casca William this bed averages about 10 feet thick, and dips 60° S. It is composed of Grey-Ash coal. The tunnel is 84 feet S. from the Big Coal bed. The gangway is about 1500 feet long. Between the Big Coal bed and Black Heath bed there is a pebbly rock.

It is same as the Big Coal bed of Silver Creek. It is worked by Miller's Slope on the Big Seam at Mount Laffee. It is 12 feet thick, and dips 55° S.

Also in the tunnel, at the foot of Heilner's Slope on Wolf Creek. Here the coal is 4 feet thick.

Also in Serril's Upper and Lower Tunnels, between Wolf Creek and West-West Branch.

Under the same name, though perhaps falsely called, it is worked at Middle Creek by drift, and at Donaldson by gangway in the tunnel.

This is probably the same as the Lelar of Mine Hill Valley, and the dirt-bed of Staunton's Broad Mountain Tunnel.

Skidmore Coal.—At Casca William this seam is 47 feet N. of the Big Coal, and is 4 feet 9 inches thick.

It has been cut in Mount Laffee Tunnel on West Norwegian.

Jugular Coal.—This seam averages from 40 to 60 feet in thickness at M^cGinnis's Colliery. It is sometimes solid coal, and sometimes in several indistinct benches. When distinct, the lower bench is from 6 to 8 feet thick, and the intervening slates only a few inches; all the rest is coal, with thin slate-partings. The dip is 45°, becoming less as it is followed up. It consists of a very powdery White Ash Coal; the lower bench is a fine Pink Ash.

It has been worked by gangway at Payne's Colliery in Mine Hill Valley, where the average thickness of the coal is 30 feet, and also by gangway at Sando's, on the W. side of Dyer's Run. On the E. side it has been burning for many years past.

It has been drifted upon at M^cGinnis's on Broad Mountain.

It was supposed to be cut at the end of Adams' Tunnel north-east of Mine Hill Gap.

It has been cut in Mecke's Tunnel, where the average thickness was 18 feet, and also at Lawton's Mines.

Black Valley Coal.—At Casca William, 42 feet S. of the Black Heath, this coal, which is Grey Ash verging on Red, is 7 feet thick, and dips 55° S. The gangway is driven about 675 yards Westward. It is cut and worked in the Old Mount Laffee Tunnel.

It is also worked in the slope on West Branch at Mine Hill Gap.

It is cut in Jones' Tunnel south of Jones' Slope, and has gangways in it driven E. and W.

It is cut in the tunnel from the foot of Heilner's Slope, Wolf Creek.

It is also cut in Serril's two tunnels at the head of Wolf Creek.

It is mined in a slope-pit on West-West Branch under the name of the Forestville Coal.

This is cut at the back end of Edwards and Morgan's Tunnel, on the Forest Improvement Company's lands. It is worked by gangways at the new mines, where it is called the "White-Ash Vein."

It is worked by M^cCreary at Swatara Falls and at Middle Creek under the same name, and is said to be the same as that worked at Donaldson under the name of the Gardner Seam, and cut in the tunnel there, and sometimes called Holmes' Vein. It is probably the same as the Crosby Seam of Mine Hill Valley.

Little Peach Orchard Coal.—This is worked on the West Branch by a gin slope under the name of Oak Hill Vein. It has also been worked on Wolf Creek in a slope by Holman and Company, where it is from 8 to 10 feet thick; and also on the W. side of Wolf Creek, in a slope, by Richard Kear. Hence to the W. it is frequently called Kear's Vein.

Primrose Coal.—Worked by Jones and Mason on East Norwegian by two slopes on the N. and S. sides of an anticlinal. It is 4 feet thick.

It has also been worked by Morgan Brace on West Branch under the name of Morgan Vein.

It has been worked in a slope by Heilner, at the head of Wolf Creek, under the name of Bast White-Ash. It is from 6 to 12 feet thick.

It was worked by Bast and Pearson on the W. side of Wolf Creek. There is a slope upon it. The coal is 8 feet thick.

The Primrose Seam of Mill Creek had on the E. side of the working a bottom of 3 feet of bony coal, and 6 feet of good coal, but worked more to the W.; it contained from 12 to 14 feet of good sound coal.

The Primrose Seam is cut in Ravensdale Tunnel; the coal is there 7 feet thick. It is cut again at the end of the tunnel, where it is, however, dirty.

South Diamond Coal.—The Red-Ash Slope at Casca William, called the Luther or South Diamond Seam, has a gangway worked Eastward on the S. dip below water-level to the Hubley Tract. They have worked it up to the line of the Bushy Tract. The same coal on Bushy Tract is the second N. of the Lower Breaker, and the first S. of the ravine. It is worked through, and dips at about 55° or 60°. The dip varies, and at Daniel's is in steps. It contains clear good Red-Ash coal 5 feet thick, with a strong rocky 2-inch slate in it. The dip at the slope is 50°. It is flatter on the same level further W.

At Mill Creek the South Diamond Coal is 4 feet thick.

The South Diamond Coal, drifted from Crow Hollow eastward a short distance, is not worked on the W. side.

Big Diamond Coal.—The Big Diamond Coal of West Branch and Wolf Creek is not the true Big Diamond of Norwegian. Under that name, however, it has been drifted upon on West Branch, and was worked in 1852 by Bast and Pearson, in their slope on the W. side of Wolf Creek, where it dips S., and is 5½ feet thick.

The Big Diamond of Mill Creek is worked there by a slope, which is 450 feet down, and is 7 feet thick.

It is found to flatten in dip as it descends. About 200 feet below water-level it is flat, and then turns up. At the flat part it is more than double the ordinary thickness, but in rising on the N. dip it is crushed and worthless, and very thin.

The Big Diamond Coal is called the Green Park on another dip.

Little Diamond Coal.—A seam is worked under this name on West Branch by drift; on Wolf Creek by Heilner's Slope, and on West-West Branch by Miller's S. Slope. It is supposed to be the Big Tracey Seam, being, however, two seams under Morris's Peach Mountain of West-West Branch.

Palmer Coal.—At Milford Colliery, the so-called Palmer Vein on the S. dip is gently inclined, being not more than 18° or 20°, and is a thin coal, rarely 2 feet thick; it has therefore not been wrought far to the E. It has been worked 500 or 600 yards W. on the upper and lower gangways. On the N. dip the Palmer stands nearly perpendicular, but far E. and at the tunnel it is not so steep. It has been worked 900 or 1200 feet E. from the tunnel, and shows good coal, varying from 20 inches to 2½ feet thick, all dipping S. It has been worked at the N.E. side of Middleport by Patrick Freeman, on Hensinger's property. At Mill Creek it has been wrought by Mason and Spence by drift, and contains about 3 feet of good coal. It has also been worked on Lick Run.

Charles Pott Coal.—At Milford Colliery this seam is entered by a drift just at the mouth of the tunnel; it dips 55° S. It is worked out and closed up. The slates outside show a S. dip of 35° or 40° from the pressure of the hill.

It consists of 2 feet of good hard coal, with rock at the top and slate at the bottom. It is worked nearly as far as the Clarkson. In the tunnel it was, in 1853, only worked 45 feet each way. It dips 35° or 40° S., and is steeper Eastward. It has been worked to the E. by Dr Steinberger, and at Middleport by Billy Wall.

It has been worked W. of Middleport by Hebner. It dips S. The coal, 2½ feet thick, was not good, being faulty.

At the Five-mile Board it was worked by Bosbyshell in 1838, and by E. Collahan in 1850. Good coal 3 feet thick was found dipping S. It has been wrought by T. Williams at Lick Run, where it showed from 3 to 3½ feet of good coal, with tough blue upper slate.

Clarkson Coal.—At Milford Colliery this coal-seam dips S. It is entered at the water-level below the Breaker, and has been worked E. about 1100 or 1200, or probably 1300 yards, as far as the farmhouse S. of Patterson. There is a gangway in the old field E. of the farmhouse. The outcrop passes here to the N. of the house. This coal-seam has generally a gentle S. dip, but at the N. end of the slope it is about 55°. Here, at 75 feet below the water-level in the slope, there is a rock-fault, with a sudden upcast of 75 feet, entirely cutting off the coal, without even a leader—an unusual thing in this coal-basin. It is 5 feet thick, and was worked by Billy Wall at Middleport.

This coal-seam was opened and identified at Middleport by Mr Thompson; it dips S., and has 3 feet of coal and 3 feet of dirt; with a bone coal and slate top. It has been worked as far W. as Cwmbola, where Bolton worked it by a slope as far as Milford. It was shafted upon at intervals, and worked at Milford by S. Silliman.

Peacock Coal.—It is probable that the Lower-slope Coal of Miller on West-West Branch, known as the Cockle Vein, is the Peacock Coal of Mill Creek.

Yard or Clinton Coal.—The little seam between Miller's two slopes on the West-West Branch is probably the Yard Coal of Mill Creek, supposing the S. slope seam to be the Big Tracey Coal.

Big Tracey Coal.—The Little Diamond, so called, of the West Branch and Wolf Creek, as worked at Heilner's Slope, and of West-West Branch, as worked in Miller's S. Slope. It is the second vein under Morris's Peach Mountain Coal: it is therefore the Big Tracey Coal.

Little Tracey Coal.—This seam is shafted upon W. of Middleport. It dips S., and is 2½ feet thick. It has under it an Egg-conglomerate. At Valley Furnace it has been worked by Davis and Williams, and is 2½ or 3 feet thick. It is supposed to be the Platt Seam, which is tunneled to from Spencer's Slope on Wolf Creek.

Peach Mountain Coal.—This seam has been worked W. of Middleport on both dips of the synclinal on A. Stahl's Tract west of Casca William Tract. Its basin rises W. It has been worked by George Thompson, who feels sure it is the same as at Pottsville. At Middleport it is from 2½ to 4 feet thick, with a fine leafy roof and slate bottom 7 feet thick, under which there is a small rough seam, having the appearance of "baked bread." It has no grains of lamination, but "looks like twisted dough." It is a rather pinkish Red-Ash good coal. The same parting-slates are recognisable, but thinner.

The small coal under the Peach Mountain Coal is well known at Pottsville; it has an inch and a half of a dull coal, like coarse cannel coal, for its top plait, both at Middleport and Mill Creek. This seam has been worked at Capewell and Dovey's Slope on Silver Creek. It has also been worked on Wolf Creek, on the S. dip by a slope, under the name of the Spencer Coal; also by Heilner in drift, under the name of Kantner, on the N. dip on Wolf Creek; and formerly by Spencer at Minersville in Lewis's Old Tunnel; and since by Morris on the West Branch under the name of "Fire Vein." It has also been worked at the Delaware Mines on West Norwegian in a slope.

Spohn Coal.—This bed has been worked at Middleport by H. Uren on the S. dip. It was from 6 to 7 feet thick, and when faulty was down to 2 or 3 feet, and had the same roof and slate as at Belmont and Centre Turnpike.

It was worked S. of New Philadelphia by Connor and Roads. The slope upon it dips 30° or 35° S. The coal is 4½ feet thick.

It was cut in the tunnel driven from the foot of Milnes and Snyder's Lewis Slope under the name of the "North Vein."

It has also been worked at Branch Dale Colliery on Muddy Branch by McDonald.

The Spohn Coal of Mill Creek is supposed to be the same as the *Palmer Coal* (*Yard*) and Chestnut of Spencer and Mason, and the Engine or Little Gate Coal is therefore the Selkirk.

Some think the Spohn and Peach Mountain Coals are the same, but this is a point not settled.

Lewis Coal.—This seam has been worked by a slope on the E. side of Mill Creek by Snyder and Milnes. It is 4½ feet thick, and dips 35° S. It has two benches.

The Lewis Bed, so called, worked at Belmont and Cwmbola, is in reality the Sandrock of Mill Creek. It was worked on the W. side of Mill Creek by Haven. It is a slope colliery.

It has been worked at Belmont (Five Points) under the name of the Spohn Coal. It dips 37° S., and is 3 feet thick.

It has also been worked in a perpendicular shaft at George Miller's Works on West Norwegian; the shaft is 255 feet down. Also by McDonald at the Branch Dale Colliery on Muddy Branch. It is thought to be the same as the Main Gate Coal.

Sandrock Coal.—This has been opened by drift on the W. side of Mill Creek, but is there found in fault. It is 3 feet thick. It has been mined by slope-working at Belmont (Five Points), under the name of the "Lewis Vein," by Tyler and Agard. It is there 5½ feet thick, and dips S.

It has also been mined by slope-working, by the same firm at Cwmbola, under the name of the Lewis Seam. It is there 4 feet thick, dipping 38° S.

Big or North Gate Coal.—This has been worked at John Preston's Colliery south of New Philadelphia by drift. It contains 9 or 10 feet of good coal. It is the same as the Lewis Coal.

South Gate Coal.—John Preston has worked this mine S. of New Philadelphia by drift. It is supposed to be the same as the Little Spohn and Black Mine Coal.

Black Mine Coal.—This has been tunneled to from the foot of Oliver's Tunnel Coal-slope south of Pottsville, and mined by Fogarty and Brother on the West Branch by a slope. It is thought to be the South Gate Coal.

Tunnel Coal.—This has been worked at Oliver's Slope on the S. side of Bear Ridge. It dips 34° S., and is 5 feet thick. It was tunneled to from Fogarty's Black Mine Slope on West Branch.

It has also been worked at Chillis's Slope by Mr Berry, Superintendent. It is 4½ feet thick, and upon the top there is 8 feet of soft bony stuff. It generally has 2½ or 3 feet of this overlying matter. It dips about 40°. It consists of two benches, the lower being 2 or 2½ feet thick, the upper about the same; and between the two benches is a thin strip of soft dirt; the bottom bench is rather the best coal. It has also been mined by slope-working in Salem Hollow east of Pottsville.

Selkirk or Lawton Coal.—This has been drifted on, but not mined, on Oliver's Bear Ridge Tract. It was found to be irregular, and was thought to be the Spohn Coal.

Rabbit Hole Coal.—At Oliver's Colliery, Bear Ridge Tract, owned by Shippen and Whitaker, and superintended by Mr Headly, the first S. seam opened and worked is the Rabbit Hole. It has been drifted on, and is 3½ feet thick.

In Salem Hollow it is 2½ feet thick, and hard.

Faust Coal.—This has been cut in Berry's and Randolph tunnels.

Salem Coal.—This has been cut in Berry's Tunnel, and also in Randolph Tunnel.

It has been worked at Heilner's Salem Colliery on West-West Branch below Llewellyn.

Mammoth or Daniel Coal.—This has been worked by Adams and Miller at Coal Castle, by George Payne at Heckscherville, and by John Staunton at Glen Carbon. It is from 16 to 20 feet thick, as worked by Lewis Dougherty. It has also been worked by Heilner. At Dougherty's it dips 65° or 70° N., and at Adams and Miller's from 45° to 55° S.

It has been worked at Charles Miller's Slope on Mine Hill at the head of West Norwegian; also at Miller's (?), West Branch Gap, and again under the name of "Back Vein" at the end of the tunnel from Heilner's Slope Vein on Wolf Creek; also in Serril's Lower Tunnel.

It has been worked by Jones and Mason on Mine Hill at the head of East Norwegian. There is a slope upon it. This is the same coal as the Big Coal of Casca William, and the Big North Coal of Silver Creek.

There is a slope upon it at Adams' Pine Knot Colliery, where it has been worked.

It has been drifted upon at McGinnis's on Broad Mountain, and worked in Hill's Tunnel on the N. dip of Mine Hill; also by Heilner at West Branch Gap, and by Dougherty at the same locality.

It has been cut in Mecke's Tunnel, and cut and worked in Staunton's Tunnel.

Crosby Coal—probably the Black Valley Coal.—This has been worked at Payne's Colliery, and cut and worked in Staunton's Broad Mountain Tunnel on the S. dip, under the name of the Big South Vein.

In all probability it is the same that is worked at the end of Oliver's Peaked Mountain Tunnel on the N. dip, though some regard it as the Daniel Coal-seam.

SYNONYMS OF THE COALS HAVING MORE THAN ONE NAME IN THE POTTSVILLE BASIN.

Nesquehoning Mines.—The so-called Fifty-feet Coal of the Rhume Run Arch, or saddle of coal, is identical with the so-called Twenty-eight-feet bed of the N. side of the basin of the same locality. This large bed, actually 22 feet thick, probably constitutes the lower portion of the great mass of Summit Hill. The Nineteen-feet Vein is the N. vertical; the Thirty-nine-feet bed is the Brown Vein; and the Twelve-feet bed is the Pencil Vein.

Lehigh Summit Coal.—This enormous stratum of anthracite is in all probability the representative of the chief White-Ash beds of Tamaqua—namely, of Coals B, C, D, Cross-cut, and E, united into one by the thinning-down Eastward of the strata which separate them.

Panther Creek Coals.—The lowest main Red-Ash, or more properly Grey-Ash Seam of Panther Creek, the Eleven-feet bed of Tunnel No. 8, is obviously the Red-Ash Coal F of the Little Schuylkill, and district W. of it. It is the coal of Carter's Slope E. of Greenwood Tunnel.

Tamaqua Coals.—The coal-beds A, B, C, D, D Cross-cut, E and F, the Bony Coal G, the Red-

Ash Vein, and J of the N. side of the Coal-field at Tamaqua, are the coals T, S, R, QQ, Q, P, O, O o, N, and M of the S. side.

Newkirk.—Coal C, or next N. of D in the Newkirk Tunnel, though a strong Red-Ash coal, is the equivalent of Coal C of Tamaqua.

From Tamaqua to Buckville, the coals of the White-Ash Series bear the alphabetical names allotted to them at the former place.

The Bowman Big Vein is supposed to be the Grier.

Tuscarora and Vicinity.—The "Big Vein" of the Palmer Tunnel, and of the same range W., is the Coal E of Tamaqua.

Coal F of Tamaqua is the Palmer Vein, so called, of Tucker's Slope and Palmer Tunnel.

The Tuscarora Coal is the same. F is also the Spade and Luther of Middleton.

The Grier Bed of Tuscarora is Bowman's Big Coal of Newkirk.

Tuscarora to Casca William.—The "Big Vein" of Tuscarora, of Swift's Creek, of Big Creek Mines north of Patterson, of Whitfield's Upper Tunnel, of Casca William White-Ash Mines, and of the flank of Mine Hill north of them, is undoubtedly the Coal E of Tamaqua.

The Black Heath Coal of Casca William is in all probability identical with the Palmer of Tuscarora, or F of Tamaqua.

The Luther Coal of the Red-Ash Colliery of Casca William Valley is the South Diamond Coal of Silver Creek, and the valleys further W. The Adam Stahl of this locality is probably also the South Diamond.

The so-called Palmer bed here is apparently the Peach Mountain Vein.

The Spohn bed of Casca William is a different coal from the genuine Spohn Vein of Norwegian.

Silver Creek.—The Big or North Coal of Silver Creek is unquestionably the same with the Big Coal of the country to the Eastward, or the Coal E of Tamaqua. It bears the name of the "Mammoth Vein" on Mill Creek, and thence Westward to West Branch and Wolf Creek, where it is also called the Daniel Coal.

Dodson's Coal of Silver Creek is the Orchard of Mill Creek.

The Guiterman bed of this valley is on the horizon of one of the lower coals of Tamaqua, but is not at present identified with either of them. It is apparently the Big Coal of Eagle Colliery, Mill Creek, though this is not proved.

The Skidmore Coal of Silver Creek, and the valleys Eastward, is *in position* the equivalent of the Cross-cut bed of Tamaqua, but their continuity has not been established.

The identity of the so-called Big Diamond Coal of Silver Creek and Casca William with the Big Diamond of Mill Creek and East Norwegian is by no means proved.

Zachariah's Run.—The North Diamond is here called the Gin Coal, not the Gin Coal of Silver Creek.

Mill Creek.—The *Big Coal* of Johns' Eagle Colliery is by many colliers of the district believed to be the Mammoth outcropping from the S., but there are good reasons to suspect it to be a lower seam, and identical with the Guiterman bed of Silver Creek.

The *Black Heath Coal* of other localities is here, and on East Norwegian, generally styled the Seven-feet Seam of the Mammoth Bed, which it almost immediately overlies.

The John Holmes bed of Mill Creek is the Black Valley Coal of Silver Creek and other localities.

The Big Diamond of Mill Creek is erroneously called on Lick Run the Big Tracey Coal.

The *Sandrock Coal* of Mill Creek is mined both at Cwmbola and at Belmont under the name of the "Lewis" Coal.

The true Lewis Coal of Mill Creek and the Norwegian valleys bears at Cwmbola and Belmont the title of the *Spohn Vein*, and this erroneous appellation is applied to it on Silver Creek, and still further E. in the basin; the true Spohn is mined by Connor and Roads.

The *South Diamond* of East Norwegian is called on Mill Creek the Green Park Vein, which is the Big Diamond of Mill Creek on another dip.

The Little Sandrock Seam of Mill Creek is the 3d North Gate of the same valley.

On Mill Creek and East Norwegian, the Lewis, Gate, and Tunnel coals are the same bed repeated by the flexure of the Gate Ridge. The small coal above the Lewis at East Norwegian is found above the Main Gate bed on Mill Creek.

The Lower Lewis, or Little Spohn, is the South Gate and the Black Mine Coal.

The Spohn, Palmer, and Yard of Mill Creek Valley, and Chestnut Coal of Singley's Farm, are all identical, and are the same as the Little Perpendicular Gate, or Engine Gate, and are therefore the equivalents of the Selkirk of the S. slope of Gate Ridge.

The Little Tunnel, Rabbit Hole, and Nest coals of Mill Creek are respectively the Yard, Big Sandrock, and Little Sandrock beds of the opposite dip.

THE NORWEGIAN VALLEYS.

East Norwegian.—The Cellar Coal of this valley is the Stevenson of Mill Creek.

Dado's Coal of East Norwegian is the North Diamond of West Norwegian.

The *Clinton* Coal of East Norwegian is said to be the Yard Coal of Mill Creek, and this Yard Coal is the first North Gate bed of Mill Creek, and the Peacock Coal is the Clinton of Mill Creek.

The Peach Mountain Coal of the Norwegian district is the Barclay Coal of the same in the basin South. On Middle Norwegian, the Big Tracey, Chenoweth, and Clarkson, are all identical, being only different outcrops.

In like manner, the Little Tracey and Pearson are the same.

WEST BRANCH AND WOLF CREEK.

Morgan's Coal of West Branch appears to be identical with the Primrose Coal of West Norwegian.

The Mammoth Vein on West Branch is sometimes called the Daniel Coal. The so-called Seven-feet bed of Charles Miller's Slope on Mine Hill (12 feet thick) is the *Black Heath* seam of Heilner's Tunnel.

The *Oak Hill Coals* of West Branch are the *Orchard beds* of West Norwegian. The Spencer is the Kantner bed of Wolf Creek, and both are the Peach Mountain Vein of Norwegian, all identified by actual mining.

The Pelton Coal is probably a portion of the Big Diamond bed of West Norwegian and Mill creeks.

The Big Diamond bed of Wolf Creek, known as Bast's Red-Ash Coal, is not the Big Diamond of Silver and Mill creeks, but is one coal lower in the series, for it underlies the coarse pebbly rock which forms so good a guide to it, whereas the Big Diamond of the valleys E. overlies this conglomerate. The Wolf Creek Big Diamond is therefore an expansion of the small coal which, on Mill Creek, intervenes between the Hancock and Big Diamond beds of that valley. This seam is hardly discernible on Silver Creek, and is therefore a coal of Western development.

WEST-WEST BRANCH.

Upon this valley the lower White-Ash coals of Silver and Mill creeks seem to have greatly thinned down. The Great Mammoth bed with the Black Heath, previously coalesced into one, are either gone or reduced to the 5-feet-thick seam immediately above the conglomerate of Mine Hill; and some of the six or seven still lower beds, proved and partially mined at the West Branch Gap, are here found of notable size. The Black Valley Coal is here called the Forestville Coal. It outcrops high on the S. flank of the mountain, placed there by the ending of axis E. The Black Heath Coal saddles Mine Hill near Woodside.

Bast's White-Ash Coal of West-West Branch is the Anderson Coal; also the Morgan of West Branch, outcropping there in front of Jones' Tunnel, and the Primrose of more Eastern localities. It has been worked through to Wolf Creek.

Kear's White-Ash Coal is the Oak Hill or Little Peach Orchard.

Cockle's Red-Ash Coal is the South Diamond of Silver and Mill creeks, and likewise the Oak Hill of Wolf Creek.

The Phœnix Coal is in the position of the Little Tracey of Norwegian; it is also the Little Diamond of West-West Branch and of Wolf Creek.

On West-West Branch, the there so-called Black Mine and Selkirk coals are the same bed on opposite sides of the folded anticlinal axis of Gate Range.

The Salem Faust and Rabbit Hole beds of this valley at Silvertown Colliery are likewise only one seam, repeated by a subordinate anticlinal flexure.

MINE HILL VALLEY.

At Lawton's Colliery, the Seven-feet Coal over the Lawton or Mammoth bed is the Black Heath Coal; the Eleven-feet seam at Lawton's is the Black Valley Coal.

Fogarty's Big Coal is the Pinkerton Large Seam.

The Adams Slope Coal is the true Daniel's bed, and the coal at the end of the Adams Tunnel is the Jugular Seam. These are again intersected in Payne's Tunnel.

At Oliver's Colliery in the Peaked Mountain, the Back Coal, so called, is the Big South Coal of Staunton's Tunnel, and the Crosby bed of Payne's Tunnel.

MUDDY BRANCH.

The Red-Ash bed of this locality is thought to be Kear's Coal of Forestville.

Whether the coals called the Peach Mountain, Spohn, and Lewis beds near Weaver's, are actually identical respectively with the coals of these names on Norwegian, is doubtful. The most probable equivalency is that of the Peach Mountain Seam.

Donaldson and further West.—The three large lower coal-beds of this locality, called the Big Vein, the Black Heath Vein, and the Black Valley Vein, are in all probability beds of a Western development, and not equivalents of any main seams of the districts E. Possibly the Black Valley may be represented here, but even this is doubtful, since it is reduced at West-West Branch, distant 8½ miles, to a thickness of only 5 feet. The coal called at Klinger's Gap the *Peacock*, is the *Black Heath* of Donaldson.

The Gardner bed is the better name for the so-called Black Heath of Donaldson. It is impossible, in the existing condition of mining in the Western districts of the Southern coal-field, to identify the many valuable beds of coal there, with known seams of the better-developed central tracts of the basin. There does not prevail that geographical extension of the coals in the Anthracite region, which belongs to those of the great bituminous coal-fields beyond the Alleghany Mountain, nor does either country present them in anything like the continuity very generally imputed to them.

CHAPTER XIV.

SMALL COAL-BASINS OF BROAD MOUNTAIN.

The next division of the Anthracite Coal-field which claims our attention is the Broad Mountain. A series of parallel anticlinal flexures, most of them of rather gentle curvature, occupy this table-land, and divide it into elevated belts of the Seral conglomerate, and intervening small basins or troughs of the coal strata. Two of these coal-tracts are of sufficient importance to deserve a brief description; one is at the sources of Mill Creek, the other at the very head of the West Branch. These small basins have been only partially developed. That of Mill Creek is in chief part owned by the Boston Colliery Company, who have made some progress in exploring it; while that on West Branch, at the Centre Turnpike, has never been opened, there being no ready outlet for the coal.

Broad Mountain, Mill Creek Basin.—A glance at the general map of the anthracite region will explain the position of this and of the other small basins nearly in a line with it. An important anticlinal axis, the main Southern flexure of the Broad Mountain, after lifting the red shale of Locust Valley, elevates the Seral conglomerate N. of Mine Hill Valley, and passes away Westward into Deep Valley. Where this flexure divides Wolf Creek from the Mill Creek Basin, the dips on both sides of it are very steep. The latter basin is therefore a closely-compressed one, for the S. dips of its N. side are at a very high angle. The whole basin is about 3 miles in length, and at the widest, from conglomerate to conglomerate, about a fourth of a mile broad. Its features are exhibited in the following Section (fig. 189), compiled from observations made at the Boston Colliery, near the middle of the tract.

There would appear to be about three or four beds of coal embraced within the trough, but only the uppermost of these is likely to prove permanently profitable. This coal is one of the thick beds low in the White-Ash series, the equivalent in all probability of the Jugular bed of

Mine Hill Valley. Exploratory shafts sunk upon its outcrop prove it to be about 16 or 17 feet thick, and to be for the most part in a very sound condition, the coal itself being of excellent quality. The dip on both sides of the basin exceeds 70°, but that of the N. side seems at one locality to grow suddenly less at a moderate depth. Between the two outcrops of the great bed the distance is on the average about 600 feet. The quantity of coal here must therefore be very large.

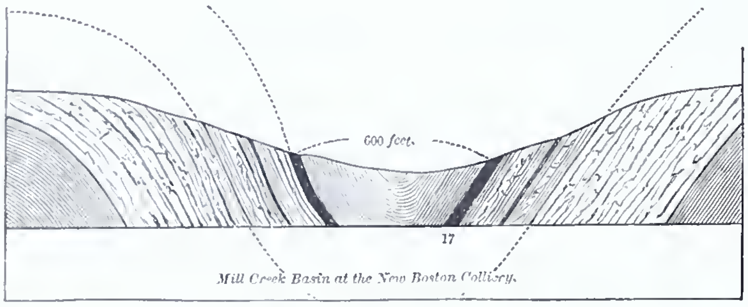


Fig. 189.—Mill Creek Basin, Broad Mountain.

Broad Mountain, West Branch Basin.—Of the coal-beds of the West Branch Broad Mountain Basin but few details have as yet come to light. The accompanying Section (fig. 190) represents its general structure and proportions.

This little mountain-basin does not promise to be a very productive one.

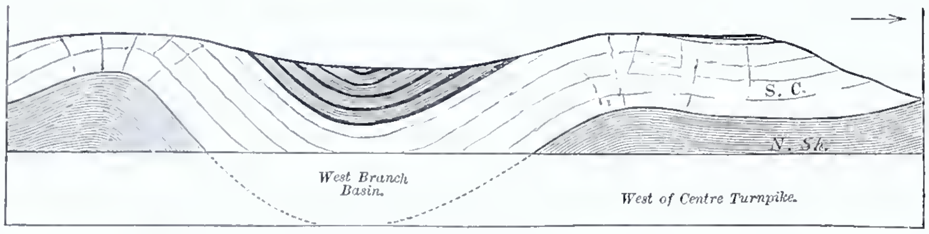


Fig. 190.—West Branch Basin, Broad Mountain.

North of the Mill Creek Basin is an anticlinal having a very gentle N. dip. This includes between it and the greater anticlinal, which ranges along the N. brow of Broad Mountain at the S. side of the Mahanoy Basin, a very small and shallow trough of the Coal-measures, not apparently deep enough to contain any valuable bed of coal. (See Section of Mill Creek Basin, W. of Boston Colliery.)

Broad Mountain, Rattling Run Basin.—The N. edge of the Broad Mountain plateau contains another very shallow limited patch of Coal-measures on the E. side of the deep ravine of Rattling Run, through which the Mine Hill Railroad now descends the mountain towards Ashland. This little basin, if such it deserves to be called, is very nearly in a line with that of New Boston; but the flexures of the central and N. parts of Broad Mountain are too obscure to enable us to connect its shallow troughs. Not more than two seams of coal had been opened in this locality at the date of observation (1853). These belong evidently to the very lowest of the series, and the basin is apparently of too flat a structure to offer much promise of its containing the big seam of the Boston Basin. The latter has escaped denudation solely because of the unusual steepness of the sides of the synclinal flexure.

CHAPTER XV.

GENERAL CLASSIFICATION OF THE COAL-MEASURES OF THE POTTSVILLE BASIN.

It is not possible, in the present imperfectly-developed state of the Southern Coal-field, to present an exact classification of the coal-formation which occupies it. We know too little of the equivalency of the beds of coal of remote localities, and of the fluctuations of the coal-measures by the thinning-away of some strata, and the introduction of others, to find it practicable to follow even the most marked planes of subdivision of the series very far. Indeed, a doubt might be raised on philosophical grounds, whether from the nature of the formation any permanent horizons of separation, coextensive with the wide coal-deposit, can exist. Nevertheless, as some general comparison between the stratification of different localities is most desirable, I shall present the best which is practicable with the data I have collected. A summary of the coal-formation, as it appears in the best-explored districts of the coal-field, and the subdivision of the entire series of coal-beds into groups, will furnish the surest elements for co-ordinating one quarter with another.

COAL-MEASURES ON LITTLE SCHUYLKILL.

The total thickness of the true Coal-measures, or the productive portion of the coal-formation on the Little Schuylkill, is about 2000 feet. This mass of strata embraces *seventeen* seams of coal of all dimensions, from 2 to 20 feet. The most natural division of the series in this district is into four groups.

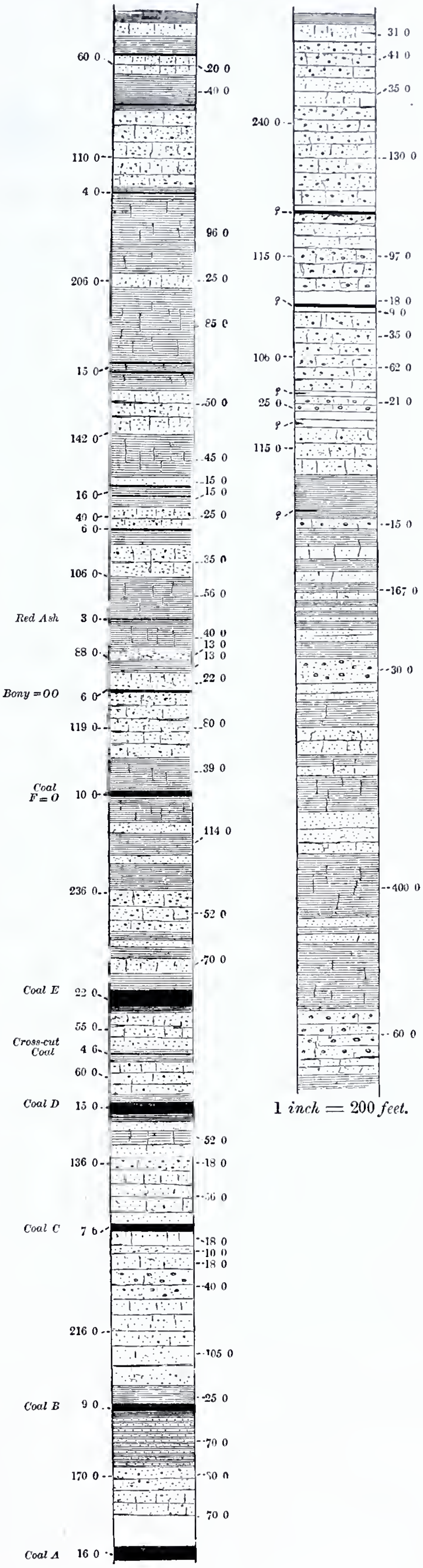
1. A lower White-Ash group, embracing all the coal-beds, four in number, from the lowest to Coal B inclusive. This division of the strata is nearly 700 feet thick.
2. An upper White-Ash group, consisting of four seams; namely, Coals C, D, Cross-cut, and E. This division is nearly 500 feet thick.
3. A Grey-Ash group of two coals; namely, F, and the Bony Vein. This group, counting from the coarse conglomerate above E to the coarse rock overlying the Bony Vein, is 325 feet thick.
4. A Red-Ash group, not subdivisible, of seven seams, commencing with the so-called Red-Ash Vein, and including the uppermost coals in the basin. This fourth division has a thickness of nearly 500 feet.

Summing together the thicknesses of these coal-beds intersected by the Little Schuylkill, and counting, not the pure merchantable coal, but everything between roof and floor, their total depth in this part of the coal-field is 120 feet, or precisely 6 feet of coal, on an average, for every 100 feet of rocks. We may abate at least one-third from this, for material not suitable for the coal-market.

COAL-MEASURES ON SILVER CREEK.

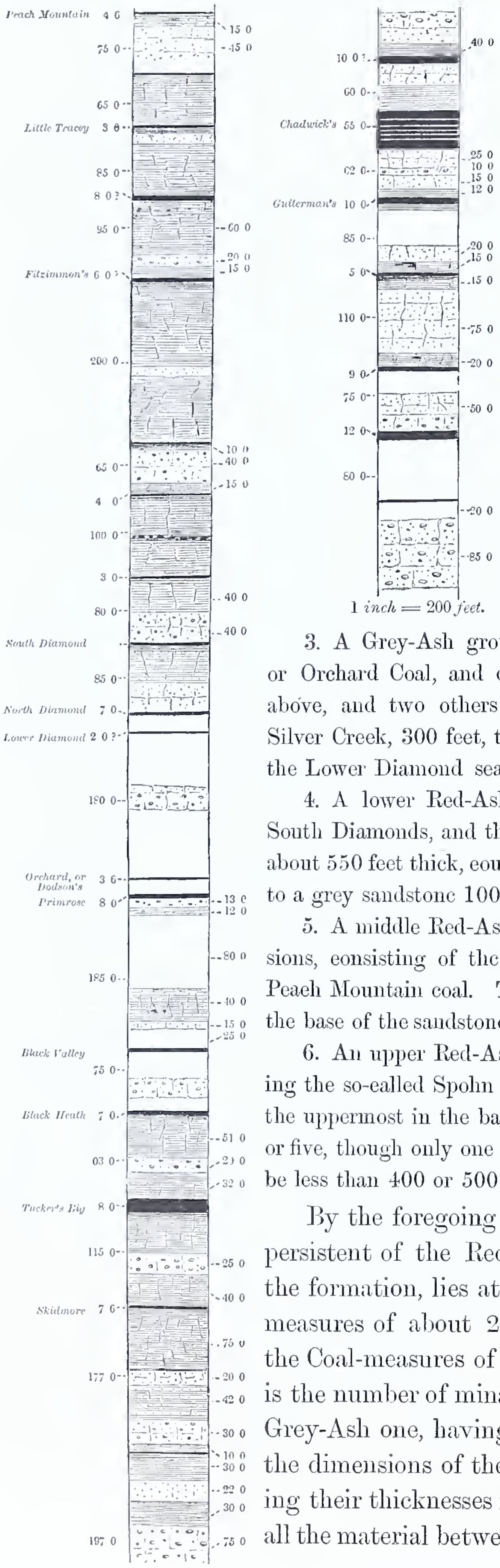
The great natural transverse section of the strata, furnished by Silver Creek, allows us to estimate the whole series pretty accurately as high as the Peach Mountain seam, but above this, from the synclinal axis to the Schuyl-

Fig. 191.—Coal Strata at the Little Schuylkill.



1 inch = 200 feet.

FIG. 192.—Coal Strata on Silver Creek.



kill Valley, the exposures are defective. Between the coarse conglomerate underlying all the coals, and the uppermost strata, S. of the Schuylkill, the total depth of strata is not less than 3000 feet. Within this mass we can identify *twenty-six* or *twenty-seven* notable coal-beds, two of which are of great dimensions. In this district the coals are separable into six groups, as follows :—

1. A lower White-Ash group, composed of seven seams, all of them, but the lowest and the fourth, being 9 feet and upwards in thickness : measuring this division from the top of the coarse underlying conglomerate to the bottom of the Egg and Nut-conglomerate, which overlies the Ten-feet-thick Coal over Guiterman's Great Bed, its thickness is about 600 feet.

2. An upper White-Ash group, embracing five beds of coal, the middle one being the Big North Coal, or Tucker's Seam, 18 feet thick, and the highest the Black Valley bed. The division of the strata embracing these coals has a thickness of 700 feet.

3. A Grey-Ash group, comprising, on Silver Creek, the Primrose and Dodson's, or Orchard Coal, and on Mill Creek the same, with the addition of the Hancock above, and two others beneath. The strata, including this group, measure, on Silver Creek, 300 feet, the upper limit being the base of a coarse conglomerate under the Lower Diamond seam.

4. A lower Red-Ash group, composed of six coal-beds, the Lower, North, and South Diamonds, and three coals above them ; these are embraced in a mass of strata about 550 feet thick, counting from the conglomerate underneath the Lower Diamond, to a grey sandstone 100 feet and more below the Fitzimmon Coal.

5. A middle Red-Ash group of five coals, all but the fourth of workable dimensions, consisting of the Fitzimmon, Big Tracey, Little Tracey, a thin coal, and the Peach Mountain coal. The depth of coal-strata embracing this group, bounding it by the base of the sandstone next over the Peach Mountain Vein, is also about 550 feet.

6. An upper Red-Ash group, embracing all the obscurely-developed beds, including the so-called Spohn Vein, overlying the Peach Mountain seam, and extending to the uppermost in the basin. The number of coal-seams here embraced may be four or five, though only one or two are known. The total thickness of the strata cannot be less than 400 or 500 feet.

By the foregoing estimate, the Peach Mountain bed, one of the most persistent of the Red-Ash seams, and therefore a good landmark within the formation, lies at a height above the conglomerate base of the Coal-measures of about 2700 feet. A survey of the entire series shows that the Coal-measures of Silver Creek are exceedingly rich in coal. Not only is the number of minable beds unusually large—each group, excepting the Grey-Ash one, having more than its average quota of such seams—but the dimensions of the coals themselves exceed the normal size. Estimating their thicknesses in the gross—that is, by the usual mode of counting, all the material between the roof and floor, namely coal, bone coal, and slate, as belonging to the coal-seam,—the aggregate amount of coal in the basin reaches the unusual quantity of 207 feet, or very nearly seven feet of coal per hundred feet of strata.

COAL-MEASURES ON MILL CREEK.

Mill Creek affords us almost as complete a section of the whole coal-formation as is furnished by Silver Creek. Though somewhat more obscure in the Peach Mountain belt, it is far more complete in the Gate Range, and in the South-dipping coal-seams of the N. side of the Sharp Mountain basin. In this district the total thickness of the productive part of the formation, counting from the upper limit of the barren conglomerate to the synclinal axis at the Schuylkill River, would appear to be, from our careful measurements, nearly 2700 feet, embracing *thirty-six* separate beds. This body of strata is divisible into the same six natural groups which it exhibits on Silver Creek, the corresponding groups differing materially, however, in their subdivisions or details; they are as follows:—

1. A lower White-Ash group, comprising five seams of coal of workable dimensions, the fourth ascending being the Great Bed of Johns' Colliery, sometimes called the Jugular Vein, the average thickness of which is 25 feet. Between the underlying conglomerate and the sandstone, above the 7-feet-thick rider of the Jugular, the thickness of strata, including these five coals, is about 500 feet.

2. An upper White-Ash group of six coals, containing, as its second seam ascending, the Great Mammoth Coal or Pinkerton's Bed, 22 feet thick. Placing the upper limit of the strata enclosing these coals at the base of the coarse pebbly sandstone which underlies the Flowery Field, or Holmes' Coal, the thickness of the division is 310 feet. The two uppermost seams are thin; the others are of workable dimensions. This group, as usual, contains some valuable nodular iron-ore, especially in the fireclay floor of its lowest coal-bed, and in the shale which overlies the Mammoth Vein.

3. A thick Grey-Ash group, including four coal-beds—the Flowery Field, the Primrose, the Orchard, and the Hancock seams. This part of the Coal-measures, making its upper limit the base of the thick sandstone beneath the Big Diamond, is about 430 feet thick.

4. A lower Red-Ash group, comprising eight Coal-beds, only two of which, the Big Diamond and the Peacock, are of a good thickness, the rest being 3 feet and

Fig. 193.—Coal Strata on Mill Creek.—1 *inch* = 200 *feet.*

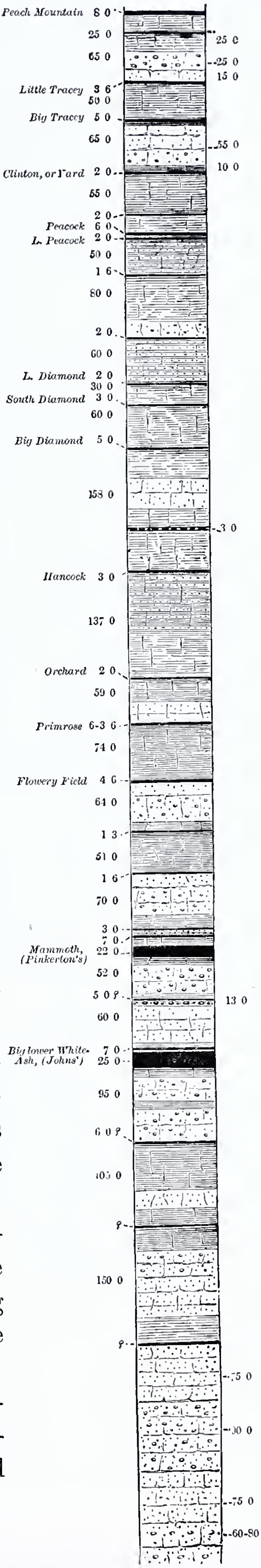
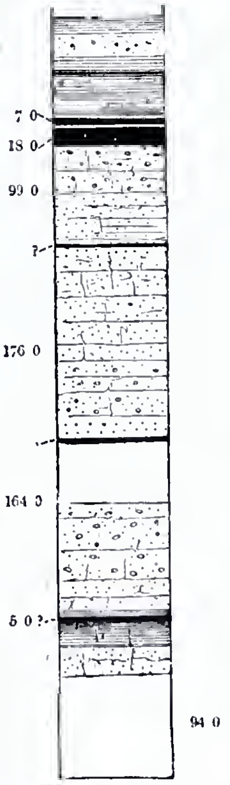
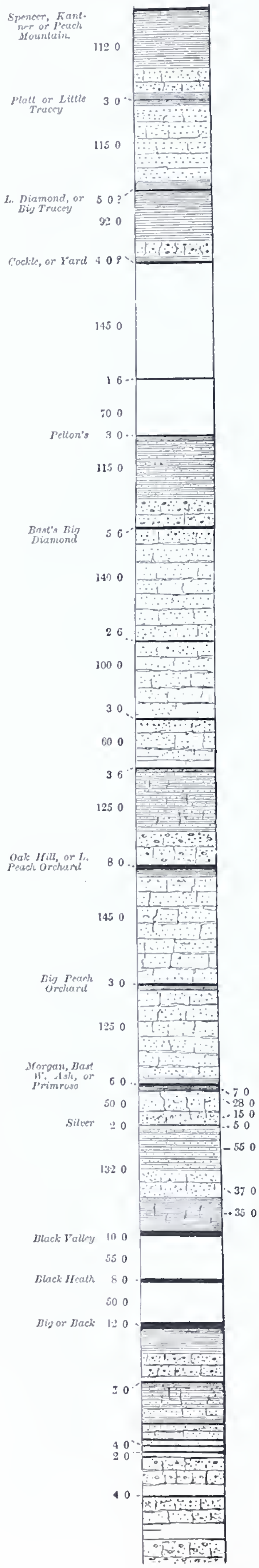


Fig. 194.—Coal Strata in the gorge of Mill Creek, opposite Wolf Creek (for comparison).—1 *inch* = 200 *feet.*



under. They are, in ascending order, the Big, South, and Little Diamonds, then two unnamed thin coals, then the Little Peacock, Main Peacock, and a thin coal, the next beneath the Clinton or Yard Seam: all these are embraced within 435 feet of strata.

Fig. 195.—Coal Strata on West Branch and Wolf Creek.



5. A middle Red-Ash group of five coals, the Clinton or Yard, Big Tracey, Little Tracey, Lower Peach Mountain, and Main Peach Mountain Beds; the Big Tracey and Peach Mountain Seams being those of principal value for mining: these all lie included within less than 300 feet of rocks.

6. An upper Red-Ash group, of less definable thickness. Assuming the Tunnel Seam of the Schuylkill Basin as identical with the Peach Mountain Vein, this uppermost group includes the Little Tunnel, the Rabbit Hole, the Nest, the Faust, the North Salem, Weasel, Main Salem, and South Salem Beds, in total number eight. The total thickness of this group, extending it to the highest rock in the coal-field, at the synclinal axis under the river, is about 700 feet.

It will be seen, upon reviewing the Mill Creek Coal-measures in comparison with those of Silver Creek, that while the lower White-Ash group is thinner by 100 feet, the upper White-Ash group is thinner by nearly 400 feet, or is reduced to less than one-half its thickness; on the other hand, the Grey-Ash measures have considerably augmented in thickness. Again, both the lower and middle Red-Ash measures are of considerably less bulk, the middle having scarcely more than half the depth they possess on Silver Creek. On Mill Creek the interval between the barren conglomerate and the Peach Mountain Coal is not quite 2000 feet. The total thickness of coal, by the ordinary method of estimation, is, at this section of the basin, about 155 feet, an average of 5 feet 9 inches for each 100 feet of strata.

COAL-MEASURES ON WEST BRANCH AND WOLF CREEK.

At the natural transverse section of the Coal-measures presented by the Valley of the West Branch and its tributary Wolf Creek, it is practicable to deduce, from the exposures of the strata, their total thickness with a fair approximation to accuracy.

Our carefully-conducted measurements make it appear, that between the top of the unproductive conglomerate and the highest strata in the synclinal axis at Westwood, the depth of the Coal-measures is not less than 2800 feet. A comparison of this section with that of Mill Creek and those of the districts still further E., shows, however, that, group for group, the Coal-measures of this part of the basin differ materially from those already reviewed. The entire series, containing about *thirty* beds of coal, may, for convenience, be divided as hitherto into six groups —two of White-Ash, one of Grey-Ash, and three of Red-Ash seams: their respective contents and dimensions are as follow:—

1. The lower Red-Ash group embraces on West Branch five beds of coal, counting from the conglomerate to the Skidmore inclusive. The largest of these is only 4 feet thick, and, what is quite as remarkable, they are all embraced within less than 200 feet of strata. So attenuated a condition of the group contrasts remarkably with its thickness and its repleteness in coal, on Silver Creek, and even on Mill Creek.

2. The upper White-Ash group, as seen on West Branch, consists as usual of four seams, a 3-feet thick bed, the equivalent of the true Skidmore, and the Mammoth, Black Heath, and Black Valley; the two first of these still thick, and closely approximated. Adopting for the limits of these strata the sandstones which insulate them from the other groups, the whole thickness is not more than 250 feet. Here again we have a nearer approximation to the state of things on Mill Creek, where, as we have seen, this group measures about 310 feet.

3. The Grey-Ash group consists here of three coal-beds—the Silver Vein, which is thin, and the Primrose or Bast's White-Ash, 6 feet thick, and the Big Peach Orchard, only 3 feet thick. Counting from the top of the underlying sandstone to the top of the overlying, the Coal-measures, chiefly sandstones, embracing these coals, show a thickness of 350 feet, a depth considerably less than that which they exhibit on Mill Creek, where, however, the Hancock Bed, the probable equivalent of the Little Peach Orchard, or Oak Hill of this Section, is included in the group. If it be embraced here, the Grey-Ash group, containing, however, a Red-Ash coal, will have a thickness of 450 feet, or that which it possesses on Mill Creek.

4. The lower Red-Ash group proper, extending it to include the Oak Hill bed as its lowest, and a small coal above Pelton's Vein as its highest, comprehends on Wolf Creek seven distinct seams, or one more than it embraces on Mill Creek, due probably to the absence, or possibly the non-discovery, of a thin bed beneath the Cockle Coal. These seven known lower Red-Ash seams are embraced in 775 feet of strata, exceeding by more than 300 feet the thickness of the corresponding division on Mill Creek.

5. The middle Red-Ash group embraces on West Branch and Wolf Creek apparently the same four coals which characterise it on East Norwegian and Mill Creek—that is to say, the Cockle, Clinton, or Yard; the Big Tracey, here called the Little Diamond; the Little Tracey, here called the Platt; and the Peach Mountain, here called the Spencer or Kantner. The division of the formation to which these coals pertain measures about 400 feet, an expansion of 100 feet beyond its thickness on Mill Creek.

6. The upper Red-Ash group of West Branch is not susceptible of quite so accurate an estimate of the number of its coals and of its thickness, as the groups beneath it. Assuming the Black Mine Coal of Fogarty's Slope Mine to be the true Black Mine of Pottsville, and the Tunnel Coal above it to be the true Peach Mountain bed on its most S. dip, the coals of the upper group of this valley hitherto developed, are five in number, though it is probable, from the size of the vacant spaces, that the whole list is not less than seven; these are embraced in 700 or 800 feet of strata.

By summing together the average thicknesses of all the coal-beds in this district, I find the total depth of coal to be 121 feet, which in 2800 feet of rocks shows a thickness of 4 feet 4 inches of coal-seam to each 100 feet of strata.

COAL-MEASURES IN THE THICK MOUNTAIN NORTH OF DONALDSON.

It is not possible to estimate the total thickness of the Coal-measures preserved in the coal-field of the Donaldson Basin; nor, indeed, with any accuracy in either of the W. branches of the

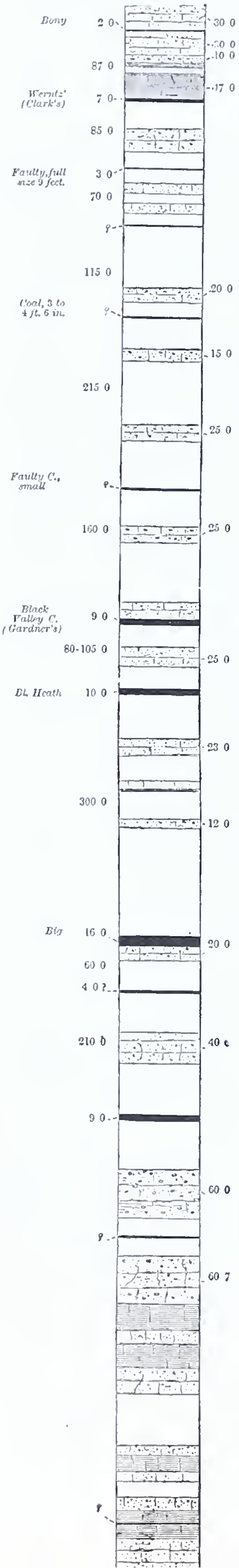


Fig. 196.—Coal Strata in the Thick Mountain at Donaldson.—1 *inch* = 200 *feet.*

main valley. We can do little more at present than indicate the remarkable change of type which the several groups of the series have undergone, in their passage from the Middle and Eastern districts of the basin to the valley of Good Spring Creek. It is not even practicable, as far W. as Donaldson, to recognise with any certainty more than a few of the groups so well discerned further E.

1. The lower White-Ash group is almost entirely obsolete, being represented by two or three very thin and impure layers of coal, outcropping among the sandstones high on the table-land of the Thick Mountain. The Section illustrating the strata on West-West Branch, shows that even there this lowest group is reduced to nearly the same attenuated condition.

2. The upper White-Ash group is richer apparently in coal than it is at West-West Branch. It embraces at Donaldson the three lowest workable seams; a bed reputed to be 9 or 10 feet thick; a thinner coal, supposed to be 4 feet, but faulty; and the so-called Big Coal, estimated at 16 feet. Counting the encompassing strata, this division of the measures embraces nearly 400 feet. The so-called Big Coal is the continuation of the Forestville seam or Black Valley bed of more E. localities, and is therefore on the confines of the White and Grey-Ash groups; indeed, one bench of it is stated to yield a grey or pinkish ash. The Black Heath Coal of Donaldson is on the horizon, therefore, of the Anderson of West-West Branch, or true Primrose, if this elsewhere persistent bed extends so far W. So again the Black Valley seam of Donaldson is the equivalent of the Orchard. Both of these are, therefore, representatives of the Grey-Ash group, unless, indeed, that group is gone, in which case they correspond to the bottom coals of the whole Red-Ash series. It would be idle to attempt to co-ordinate the remaining coals of the Donaldson Section with the several Red-Ash groups of other districts, for not one of them has been traced by mining, or even shafting, into any recognised Red-Ash coal of either Muddy Creek or West-West Branch.

RELATION OF THE COAL-BEDS OF MINE HILL VALLEY TO THE WHITE ASH GROUPS OF THE MAIN POTTSVILLE BASIN.

A comparison of the strata at the E. end of the Mine Hill Basin, and at the gorge of Mill Creek opposite the mouth of Wolf Creek, with the lower Coal-measures S. of Mine Hill, demonstrates, as our Mill Creek Section and the vertical columns will show, that the Big Coal of Lawton's Old Colliery, and of Montelius's Open Cut fronting Wolf Creek, is the equivalent of Johns' Great Seam, and *not* of the Mammoth bed situated S. of it. It is, in other words, the Jugular Coal of the Mine Hill Basin, the Daniel Seam of the more W. collieries in the basin, being the true Mammoth. The absence of the Jugular bed at the W. localities on the S. side of Mine Hill, or rather its great reduction in size at Mine Hill Gap and elsewhere, is perfectly in accordance with the law of its steady and rapid diminution to the W. or S.W. all the way from Silver Creek, where its bulk is at the maximum ; indeed, this diminution extends, with but one or two exceptions, to all the coals of both the lower and upper White-Ash groups, applying almost as strikingly to the Mammoth seam as to the Jugular itself.

A study and comparison of the several columnar Sections introduced into this chapter, will enable the reader, with very little trouble, to verify the above descriptions of the various groups of coals under the several phases they assume, and to learn the extent and the special nature of their many and curious changes.

From this description of the structure of the central belts of the coal-field, it is obvious that the anticlinals there met with are not of magnitude sufficient to lift to the surface a great thickness of the Coal-measures ; the small number of the North-dipping coal-seams, or the narrowness of these anticlinal belts, being a convincing proof that the flexures are of minor extent, compared with the depth of the whole coal-formation. They are, in fact, but folds or local *plaits* in the general mass of the South-dipping strata, which slope away with a moderate inclination from the elevated Mine Hill anticlinal towards the bottom of the S. trough at the N. foot of the Gate Ridge, or the deeper one at the base of the Sharp Mountain. It must follow from this fact, that between the crest of Mine Hill (where alone the conglomerate floor of the whole coal series is lifted to the surface) and the uppermost strata of the S. basins, there exists an enormous thickness of the coal-bearing rocks, and a correspondingly large number of separate seams of coal. The precise aggregate thickness of the Coal-measures, and the exact number of distinct beds of coal rejecting their repetitions, are questions remaining in some doubt, for it is not practicable at the present time to determine for this part of the coal-field the true place and identity of every bed ; nor do we know what allowance to make for reductions of thickness from compression and slipping. Yet I have been enabled to offer, in the preceding chapter, an approximate determination, which may not be without its interest and utility to the reader, and to the explorer of the region. If we assume the total thickness of the Coal-measures, between the top of the conglomerate of Mine Hill and the highest Red-Ash coal at the Schuylkill, to amount to about 3000 feet, we shall not be very far from the truth ; nor shall we commit an error of more than one or two beds, *if we assign twenty-five as the total number of coal-beds of workable dimensions.* To these there must be added nearly an equal number of thin seams and bands of coal, generally neglected on account of their unprofitable size. This estimate will make the whole number of separate beds of anthracite preserved from denudation not much short of *fifty.*

It must be apparent from the foregoing evidence of the dimensions of the Coal-measures, and the number of the coal-beds, that the bold assertion often indulged in that the Big White-Ash bed lies at the easily accessible depth of a few hundred feet in the middle and southern parts of the coal-field, is absurdly erroneous. Nothing but gross ignorance could have prompted to the costly borings undertaken to reach the White-Ash coal on East Norwegian, and at the anticlinal axis of the Gate Ridge, near Pottsville.

CHAPTER XVI.

FAULTS AND SLIPS OF THE STRATA.

Important effects have been produced upon all the inverted coal-seams to the S. of the synclinal axis of the Sharp Mountain Basin by the excessive pressure exerted upon them at the time they were elevated and inverted. Throughout nearly the whole extent of the Sharp Mountain the coal-seams and the softer argillaceous beds bear the marks of their having suffered a movement in the direction parallel with the plane of stratification, analogous to the sliding which takes place between the adjacent leaves of a ream of paper when one side only is lifted. In some of the seams nearly the whole body of the coal itself has been crushed into fragments, and the bounding surfaces of these are brightly polished by the mutual rubbing they have undergone, and one bed of the Sharp Mountain, called hence the Plumbago Seam, has nearly all of it been converted into small lenticular flakes, of a lustre and colour somewhat resembling black-lead. Another effect of this slipping of the coal upon itself is a warped or twisted folding of the coal-seams, and their alternate contraction and enlargement by undulations in their confining strata. Thus the levels in some of the gangways have a decidedly serpentine course, and similar undulations of roof and floor are visible in the direction of the dip. It must be apparent from this statement, that the coal-beds of the Sharp Mountain can in very few instances repay the miner the cost of entering and working them, and experience has already amply demonstrated their general unfitness for mining.

Tunnels several hundred feet in length have been driven through these coarse silicious strata to get access to the thick White-Ash coal-beds near the bottom of the series, but in every instance the coal, when reached, has been so excessively crushed as to prove unprofitable.

In the following generalised Section (fig. 197) of the Sharp Mountain, an attempt is made to show the character of the crush which the strata have undergone.

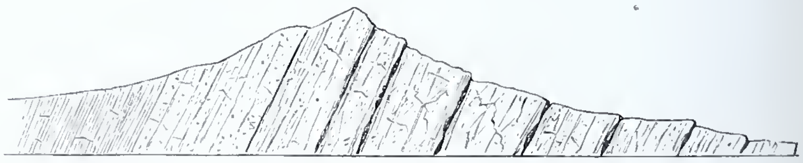


Fig. 197.—Section of the Sharp Mountain, looking W., showing overtilted strata and crushed coal-seams.

An important class of disturbances producing faults and slips of the strata are the steep anticlinal flexures. The most conspicuous of these in the Southern basin is the anticlinal wave of Mine Hill. The position and longitudinal extent of this axis are shown upon the Map, and have been already spoken of; but the present is the proper place in which to explain the special influence of this uplift in its effects upon the Coal-measures which dip away from it. It is a beautiful example of that form of anticlinal which I have denominated, in my general Chapter on Structure, the *normal flexure*, displaying a gentle inclination of the strata upon its S. side not exceeding 20°, and a dip as steep as 60° or more on its N. It is therefore an oblique arch, and the axis-plane, or that which bisects the curve, is not perpendicular, but dips steeply to the S. From this attitude of the strata in the ridge, and also from the far greater denudation which its N. flank has suffered compared with its S., under the floods which have poured Southward against it from off the long slope of the Broad Mountain, the Coal-measures of the S. slope of Mine Hill rise to a much greater height upon its side than those of its N. The lower coal-beds of the series are extremely valuable, both on account of their dimensions and their excellent quality, and on the S. side these occupy a position extremely favourable to their being extensively and successfully wrought; and they have, therefore, become the site of some of the most important collieries of the district. But upon the opposite or N. side of the ridge, the crest of which exposes the Seral conglomerate, the coal-rocks ascend the slope too short a distance to present any useful amount of breast above the water-level. This arises in part from their having, as already stated, been more washed away, and in part from their presenting steeper dips.

There is a very different amount of N. dip in the two sides of the Mill Creek Gap: for on the W. side the inclination is 60°, on the E. it is 80°. There has therefore happened at this point a transverse or N. and S. dislocation, arising from a horizontal as well as an upward pressure.

Similar cross-fractures are discernible in a difference of dip in the opposite valleys of many of our mountain-gaps, as at the Delaware Water-gap; and they will be found to be in very many instances connected with the leading anticlinals, or more frequently still with great *dislocated anticlinals*, which ar ethe principal longitudinal faults of the country.

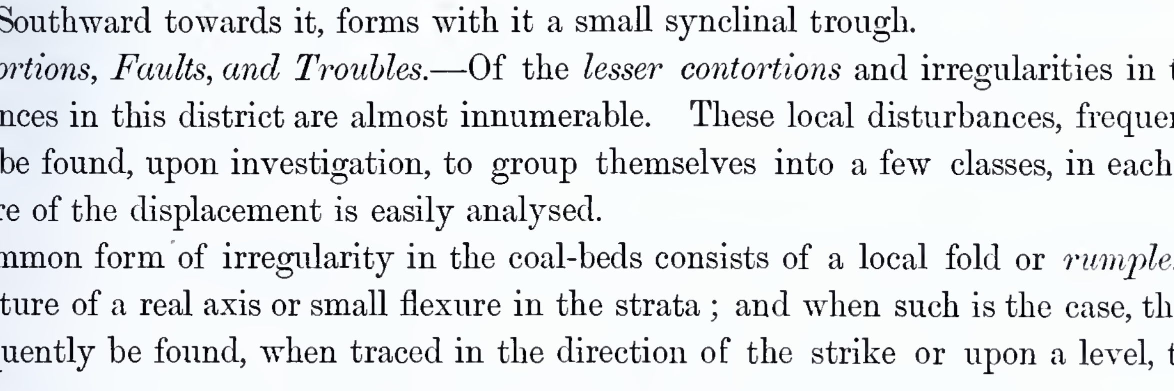
An important feature of the Pottsville Basin, well deserving to be noticed, is the more undulated character of the strata in its S. and central portions. There the anticlinal flexures display a strikingly greater inclination of their N. over their S. branches. They possess, in other words, the characteristic oblique form. Throughout the greater part of the district usually three such well-marked anticlinals occupy the middle portion of the valley, while other contortions of less length are variously interposed among them.

It is a matter of very general observation, that whenever the North-dipping coal-beds are very highly inclined or perpendicular, as they very frequently are, they are more or less crushed and irregular, and of no lasting profit to the collier; and it is, moreover, well known that they are of comparatively shallow depth, turning up into the next adjacent South-dipping seams on their North, to form, with these, narrow and local oblique basins. These features are exemplified in the Lewis and Spohn veins of Middle Norwegian, where an anticlinal N. of the main regularly South-dipping Lewis Vein is connected with a very steeply inclined North-dipping coal, which is faulty and crushed, and which at no great depth unites with the so-called Spohn Vein, which, dipping Southward towards it, forms with it a small synclinal trough.

Contortions, Faults, and Troubles.—Of the *lesser contortions* and irregularities in the strata, the instances in this district are almost innumerable. These local disturbances, frequent as they are, will be found, upon investigation, to group themselves into a few classes, in each of which the nature of the displacement is easily analysed.

A common form of irregularity in the coal-beds consists of a local fold or *rumple.* This is of the nature of a real axis or small flexure in the strata; and when such is the case, the fold will very frequently be found, when traced in the direction of the strike or upon a level, to smooth

Fig. 198.—Flexure in Red Mountain Coal-bed, Lorberry Creek.



a, Anticlinal axis, drooping away at X.
b b, Crop continued Eastward to the regular S. dip c c.
From a to X 400 feet.

itself out and disappear in the general dip. An illustration of this irregularity is here given (fig. 198), taken from the Red Mountain coal-bed on Lorberry Creek in the Swatara district.

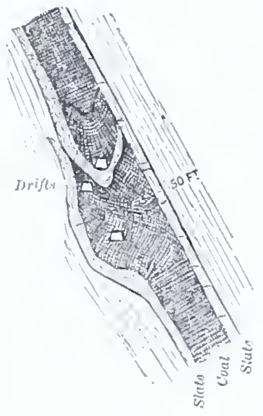
Contortions of the coal-beds unaccompanied by fracture are very numerous in some portions of the coal-field. Where the flexure reaches its maximum degree, the short leg of the anticlinal becomes of course inverted, and then the coal in all this part of the bed, and at both the anticlinal and the synclinal elbows, is in a compressed and fragmentary state. There are other irregularities of the coal arising from a sudden change of inclination, once or oftener, within a small space. Such usually announce proximity to a crushed axis, or, what is the same thing, to a longitudinal dislocation, which is but the extreme limit of the displacement that, towards its termination, closes and becomes a mere fold or axis.

The actual displacements or breaches of contact in the coal may be divided into two classes; one embraces every form of disturbance in the coal-bed parallel to its dip, the other every variety of cross fracture. The first might for convenience be called *parallel slips*, the others are named by their usual title of *faults* or *cross fractures*.

In very many instances the parallel slips present an extensive disturbance of the mass of the coal-bed within itself, without more displacement of the roof and floor than amounts to a series of local bulgings and contractions of the layer. The coal has rubbed upon itself, and is in a more or less fragmentary, friable, and polished state. To admit of this parallel displacement or moving forward of one part of the bed upon the other, there must have arisen somewhere, it is obvious, either a fracture or a doubling upon itself of the roof or the floor, or of both. It has been already shown that the Sharp Mountain beds illustrate to an extraordinary degree this form of displacement by parallel slipping.

Not infrequently the miner comes upon fractures in the roof or the floor of his coal-bed, which explain to him the origin of local parallel dips. In these cases, the one boundary of the bed giving way, and not the other, the forward movement of the coal causes one of the broken portions of the roof or floor to pass by or overlap the other, and even to bend and curl up under the prodigious pressure applied to it. This is exemplified in the accompanying Section of a disturbance of this nature in the great bed of Lorberry Creek, where the floor has broken, become involved in the sliding coal, and curved back upon itself until it has met the roof. At this point the bed, the proper thickness of which is about 27 feet, has been swollen by the overlapping of its splintered ends to a size of 50 feet.

Fig. 199.—Section of a Swell in the Big Coal of Lorberry Creek, Pinegrove.



Of the other class of displacements, the cross fractures or true faults, little need be said here in detail. Where they range with the strike or course of the strata, they will be found to terminate generally in anticlinal folds or flexures, first closely compressed and crushed, but farther on becoming more regular, and at last dying out into the general dip. Such longitudinal faults bring a rock-wall against the lower end of the coal-bed, and in each instance where a valuable vein is thus abruptly cut off, it becomes a problem of much practical interest to determine the *direction* in which the lost portion of the coal-bed is to be sought.

It may be accepted as a *general rule*, not without its occasional exceptions, that these longitudinal faults consist of an *upthrow of the vein to the S.* of the fault, so that the remainder of the vein, if we are mining downward, will be recovered at a point above, and further back towards the outcrop, compared with the spot where the rock-wall crosses the mine. Tracing such a fault through its successive stages, we shall generally be able to resolve it into a *broken* oblique flexure, and then into a gentle normal one. The three conditions of the dislocated flexure are illustrated in the diagrams here annexed.

Another species of cross fracture or dislocation is where the break is *transverse* to the strike or course of the strata, sometimes perpendicular to it, sometimes oblique. These displacements bring a rock-wall abruptly against the vein in the direction of its length, or, in other words, at the end of a gangway or level; and only when they are oblique do we encounter them also in the direction of the dip. When traced for any considerable distance across the strata, such a fault will be found to be connected with a difference in the slope of the beds upon its two sides, the one portion having been more uplifted than the other, and therefore shoved forward beyond it. Allusion has been already made to an instance of this sort on a striking scale in the N. side of Mine Hill, at the passage of Mill Creek. Another example is to be seen in the gap at the Panther Head, near Pinegrove; and within the mines in the Pottsville district many more such cases, though generally upon a lesser scale, are to be met with. These are all to be explained by some inequality in the transverse pressure, propagated Northward or Southward to the dislocated strata; and this inequality will usually be found to proceed either from the sudden rising of an anticlinal flexure to the N. or S. of the position of the fracture, or from the sudden termination of a longitudinal dislocation. Where an *obliquely* transverse fault divides the strata, we shall usually discover that the most uplifted set of rocks has been shifted forward beyond the termination of the other less inclined portion.

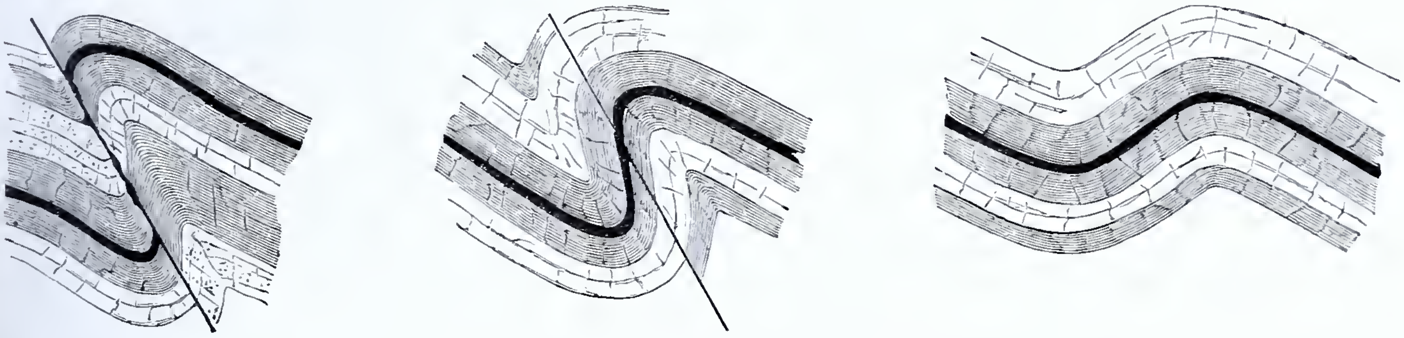


Fig. 200.—Successive Phases of a Dislocated Flexure.

Besides the foregoing varieties of transverse displacement, the collier encounters innumerable cases of lesser degrees of fracture and crush disturbing the regularity of his coal-beds. Sometimes the fault amounts to only a trivial heave of the bed, leaving a thin leader to guide him to the displaced portion. The shivered condition of the strata attending such irregularities is sketched in the little Section here annexed (fig. 201).

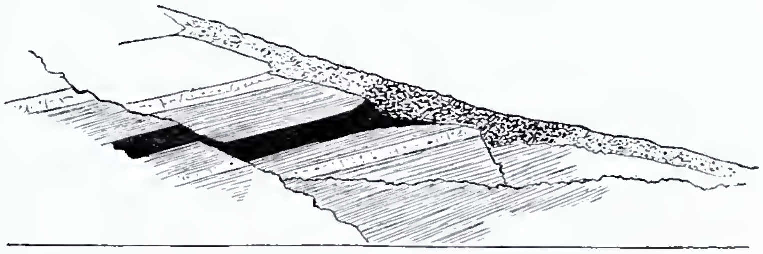


Fig. 201.—Cross Fractures displacing a Coal-seam.

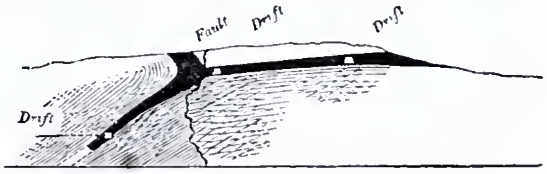


Fig. 202.—Dislocation causing a Double Outcrop at Peach Mountain Seam near Minersville.

Another less common form is shown in the following sketch (fig. 202), which represents a curious disturbance in the Peach Mountain coal-bed near Minersville, where the transverse pressure, besides breaking the strata, has bent up the end of the coal-bed into a perpendicular position past the remaining fragment of the seam, which has been left nearly flat. There have thus been formed two separate outcrops. A similar fault occurs in the Peach Mountain Coal on Silver Creek.

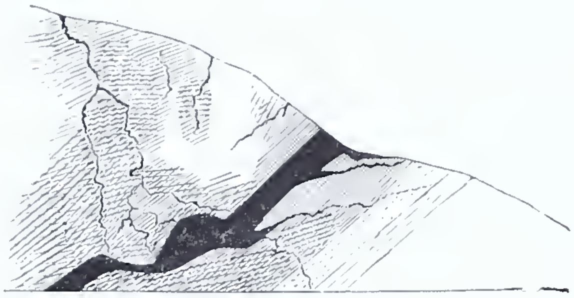


FIG. 203.—Section of "a Trouble" in a coal-seam.

An irregularity much more frequently met with than either of the foregoing, is that crushed and disordered condition of the coal-bed, which properly deserves the name of a *trouble.* It usually accompanies a somewhat shattered condition of the adjoining strata, where there has been a partial transverse movement, not amounting to a distinct cross-fracture or fault. It is a displacement of the coal in directions intermediate between the strictly transverse and the parallel, and therefore partakes of the features of the true fault and the slide. A common form of these troubles is shown in the diagram (fig. 203).

It is of the greatest importance in mining that the collier should make himself familiar with the derangements of the strata in his particular district and neighbourhood, so as to determine for himself, if possible, the prevailing character and direction of the displacements. An intimate acquaintance with the underground workings in the adjoining mines, will very frequently show him that these follow a certain rule or law, and it will teach him to infer, from the presence of peculiar signs of irregularity, not only the nature of any fault or derangement which he may be approaching, but the readiest means for either avoiding or passing through it. It is greatly to be regretted that a sound acquaintance with geological principles, especially those laws of structure which furnish so admirable a key to the complexities of our Appalachian Chain, is not more generally diffused among the colliers, mining engineers, and others, who have the conducting of our now extensive mining operations in Pennsylvania. Every well-wisher to the S. Commonwealth, the interests of which are becoming more and more bound up with the prosperity of her mines, must earnestly desire the education of her mining population, out of whose intelligence and invention alone can arise the wisest economical applications of the great mass of capital which her coal-fields are soon to absorb. I cannot close this present discussion of the derangements of the coal strata, which so frequently baffle the perseverance and waste the resources of our miners, without pressing upon the attention of all interested in our collieries the vast importance of some organised plan for the construction and preservation of a regular series of *mining records,* through which full information may be gained at any time of both the present and the past situation of all the important workings. Already vast underground tracts have been wrought out, and should no permanent registration be made for the guidance of future operators, time will inevitably efface the recollection of essential details, until it will be impossible to ascertain, except through fallacious traditions, the real boundaries of the coal, and especially the nature of the faults which so frequently suspend for a lapse of years the prosecution of certain mines. In this uncertainty, frequent misapplications of enterprise, a large waste of capital, extensive damage to property, and even serious loss of life, must inevitably be incurred, and with a yearly increasing liability, as the old workings become more numerous. England, ever watchful of her industrial interests, and awakened to the long-neglected importance of this subject, has secured the future prosperity of her vast mines by establishing, on a scale of great liberality, an office for the preservation of such mining records of every description. Let Pennsylvania think of her own future necessities, and profit, while there is yet time, by the valuable lesson which the exigencies of the mining art have taught the Government of Great Britain.

DIVISION II.

EASTERN MIDDLE ANTHRACITE COAL-FIELD.

CHAPTER I.

GENERAL STRUCTURE AND TOPOGRAPHY.

The Eastern Middle Anthracite coal-field of Pennsylvania is bounded on the S. by the Red-shale valleys of the Quakake and the upper Catawissa, on the N. by that of the Nescopec, on the E. by that of the Lehigh, and on the W. by the branches of the valley of the Catawissa. It comprises a high rolling table-land, of a maximum elevation above the level of the sea of a little less than 2000 feet. It is penetrated from the E. and W. by two sets of main anticlinal undulations, some of the longer of which pass each other in the more central portions of the plateau, while others almost unite to form continuous anticlinals through it. By a law of structure prevalent in many districts of the Appalachian Chain, where the upper rocks left by denudation are firm and resisting ones, and the strata beneath them readily eroded, these anticlinals invariably enter the coal-field by deeply denuded valleys or coves, the mountain-spurs enclosed between them being habitually of synclinal structure. Viewed in another aspect, the main basins of the district, traced E. and W., throwing off the form of valleys, run out into high insulated synclinal mountain-spurs; while the anticlinal ridges leave the table-land under opposite features, passing from the configuration of long narrow ridges, separating the basins into the hollows or coves which, in both directions, make down into the Red-shale valleys of the exterior country.

Viewing the flexures of this complicated coal-field in a large way, the whole district naturally divides itself into six leading synclinal belts, separated by five general anticlinal ranges, both the synclinal and the anticlinal tracts consisting rather of chains of basins and saddles, than of simple continuous flexures. Before proceeding to a detailed description of the individual lesser saddles, and the basins of coal embraced between them, it will be expedient to indicate these larger features, and to classify the great anticlinal belts, and the general coal-basins which they separate.

ANTICLINAL BELT No. 1, OR THAT OF PISMIRE RIDGE.

The first anticlinal belt advancing N. is that of the long and wide cove or valley of Umbral red shale, entering the region from towards the Lehigh between the E. spur of Spring Mountain and Pismire Hill, and occupied by Laurel Run and the Indian House swamp. This main anticlinal axis, leaving the Red-Shale Valley by a hollow in its N.W. corner, N. of Pismire Hill of Beaver Meadow, pursues its course Westward through the crest of Pismire Ridge, or the ridge which at the turnpike road separates the North Beaver Meadow from the Dreck Creek basins. Reaching the waters of the Catawissa, the flexure follows the denuded Red-Shale Valley of that stream to where it turns to run Southward, near the W. side of the Powell Lands; but how far it is prolonged into the Green Mountain of Catawissa, or whether it passes entirely through it into the Catawissa Valley, are points not as yet determined; it probably, however, dies out in Green Mountain.

From the cove N. of Pismire Hill, to Catawissa Creek W. of Cross Run, the anticlinal axis is arched only by the main conglomerate rock of the base of the Coal-measures, while E. and W. this stratum has been denuded along it, and the Red Shale is exposed.

Coal Basin No. 1, *or that of Beaver Meadow.*—Between Spring Mountain as a Southern boundary, and the above-mentioned anticlinal Pismire Ridge as a Northern, Basin No. 1 of the district, or that of the Beaver Meadows, occurs. As a detailed analysis of the structure and contents of this interesting coal-field will be introduced after this preliminary sketch, it will suffice to mention in this place that this basin is forked E. and W. by the intrusion of subordinate anticlinal axes penetrating it from both quarters, very much as the larger anticlinals enter and traverse the general table-land.

ANTICLINAL BELT No. 2, OR THAT OF CATAWISSA RIDGE.

This is a Western anticlinal, entering the coal region from the Red-shale district of the Catawissa. The axis appears to enter the table-land by the cove of Red Shale which divides the middle from the most southern of the three bold western knobs in the Green Mountain. Thence crossing the South Tomhicken or Mud Run, it ranges as a long straight anticlinal ridge between the Big Tomhicken and South Tomhicken of Catawissa on the S., as far at least as the Eagle Swamp; indeed, this axis is probably prolonged Eastward nearly to the Tamaqua and Wilkesbarre Road. The same general anticlinal belt, not carrying, perhaps, the same axis, but another a little N. of it, runs forward, in what is called Dreck Ridge, as far indeed as the passage of Hazle Creek, through this anticlinal. This Eastward extension of the anticlinal belt seems to terminate in East Pismire Hill, somewhere E. of Hazle Creek.

From the South Tomhicken to the neighbourhood of Eagle Swamp, the Western anticlinal of the belt, or that of Catawissa Ridge, exposes the upper beds of the Umbral red shale at various points along the axis, while at intermediate places this is overarched by the lower beds of the conglomerate.

Coal Basin No. 2.—This is the narrow and straight trough of lower Coal-measures confined to the valley of Dreck Creek, and to the same depression prolonged across the Tamaqua Road towards the W. It terminates towards Cross Run of Catawissa Creek, but a thin covering of Coal-measures extends N.W., forking off, as it were, from this basin, to lap across the Eastern subsided end of the anticlinal of the Catawissa Ridge westward of the Dreck Creek axis; thus uniting the Dreck Creek basin proper with a long narrow synclinal belt of Coal-measures of the Big Tomhicken stream N. of the Catawissa Ridge. It is this oblique passage of a strip of Coal-measures from the Dreck Creek basin into that of Big Tomhicken, which has led to the prevalent error of these being one and the same basin extended.

ANTICLINAL No. 3, OR THAT OF COUNCIL RIDGE AND LITTLE TOMHICKEN VALLEY.

This anticlinal belt, dividing the third or Hazleton basin from that of Big Black Creek, is composed of apparently three anticlinals, not strictly continuous with each other, but each more Western one originating a little N. of that next E. of it.

The First axis of the belts, advancing from the Lehigh, enters the table-land of conglomerate and coal N. of East Pismire Hill, and passes through the deeply-excavated gorge in the mountain called the Owl Hole. Further W. it is the anticlinal of the high broad ridge crossed by the Rockport and Conyngham Road, which is sometimes called Council Ridge, and which I propose to entitle East Council Ridge. This axis here forms a broad crest of conglomerate. S.W. of the new colliery village called Fillmore, a small oval patch of Red Shale is exposed by denudation ; on the line of this axis, and a little further W., the saddle enters the Red-Shale Hollow in the Eastern end of the true Council Ridge.

The Second or middle axis of this anticlinal belt is that of the true Council Ridge, or the broad long hill which separates the Hazleton from the Black Creek coal-basins. This anticlinal is traceable from the wide deep Red-Shale cove excavated in the end of the ridge, Westward as far probably as Cranberry Creek ; indeed, it is not improbable that it and the anticlinal of Little Tomhicken Valley, traceable Eastward as far as Cranberry Creek, are one and the same axis.

It elevates the upper Umbral rocks, sometimes the upper layers of the Red Shale, and sometimes the yellow sandstones which lie between these and the conglomerate, in a narrow belt along nearly the entire length of the summit of Council Ridge, the N. and S. slopes of the wave being formed of the conglomerate.

The Third division of the third anticlinal range is traceable Eastward through the regular Red-Shale cove or valley of Little Tomhicken Creek to about the Western side of the Powell Lands, beyond which Eastward the axis is saddled by conglomerate for almost its entire distance to Cranberry Creek. Only in one place, or less than a mile W. of that stream, do the lower Coal-measures encroach from both sides towards the summit of this anticlinal arch.

Coal-Basin No. 3, or that of Hazleton.—This, apparently the most capacious of the coal-basins of the district enclosed between the anticlinal ranges Nos. 2 and 3, extends as a continuous but somewhat complicated belt of coal strata from a little E. of the Board Yard in the valley of Hazle Creek westward even to the junction of the Little and Big Tomhicken. It seems to terminate E. in two blunt prongs, divided by a broad low anticlinal of the conglomerate, and subsides a few hundred yards to the N.E. of the Board Yard. Westward it forks in a much more conspicuous manner, being separated by an anticlinal ridge of conglomerate at Cranberry into two long branch basins, the more Southern one ascending Eagle or Cranberry Creek, and prolonging itself through the valley of Big Tomhicken, while the more Northern, ranging W. and N. of Long Run, terminates in the Powell Lands north of the Horse-shoe Swamp, in the watershed which feeds the Sandy Run of Black Creek, and the Little or North Tomhicken. Connected with this third synclinal belt of the Coal-measures are the two Southern small basins of the Buck Mountain Company, on East Pismire Hill.

ANTICLINAL No. 4, OR THAT OF EAST BUCK MOUNTAIN, BLACK CREEK RIDGE, AND RACOON VALLEY.

In this general anticlinal belt, the individual axes of elevation are less connected than in any of the preceding ones. At least two anticlinals lift the conglomerate between the W. head of the Red Shale cove of Sandy Creek of the Lehigh, and the Coal-measures of Cross Creek flowing into Black Creek. The rapid subsidence W. of these axes allows the lower Coal-measures to spread themselves in a broad high undulating tract W. of Cross Creek, and between the better-defined valleys of Black Creek and Little Black Creek.

Further W. in this tract of Coal-measures originates an anticlinal ridge, called Black Creek Ridge, lifting the conglomerate between the two valleys, about 2 miles E. of the Wilkesbarre Road. This, which may be regarded as the middle axis of the belt, crosses that road at its intersection with Muddy Run of Big Black Creek, ranging thence W. until it expires somewhere N. of the mouth of Little Black Creek. This anticlinal exposes a broad belt of the conglomerate, divided in its centre by a long narrow oval tract of the red shale, exposed by denudation of the conglomerate where the axis is highest.

The third special axis of the belt is one which penetrates the table-land E. from the Red Shale Valley of Racoon Creek, exposing the red shale as far as to within a mile or less of the N.W. corner of the Powell Lands. The axis is saddled from thence to its intersection with Cranberry Creek by the conglomerates beneath the coal, this part of its course being along the flat summit of the broad ridge bounding the main Black Creek on the S., and which terminates W. in the synclinal spur called the Little Sugar Loaf Mountain. This anticlinal seems to subside somewhere S. of the junction of Little and Big Black creeks, its range being considerably S. of that of the middle axis of the belt.

Coal-Basin No. 4, *or that of Big Black Creek.*—This division of the coal-field lying between the anticlinal range of the Council Ridge on its S.; and that of Black Creek Ridge and East Buck Mountain on its N., consists of two synclinal patches of the Coal-measures, the E., and by far the longest and most important, extending from near the Owl Hole westward, down the valley of Big Black Creek, to the intersection of this with Little Black Creek ; the Western consisting of an unimportant narrow and shallow trough W. of Cranberry Creek, and heading near the sources of Barn's Run. From Jeddo westward to the mouth of Little Black Creek, the basin is of simple structure, but eastward it forks into at least three divisions, the most prolonged and widest of which is that of the Fillmore and Buck Mountain Northern Basin.

ANTICLINAL No. 5, OR THAT OF CONYNGHAM VALLEY.

The next and last main anticlinal belt traversing this coal district, is one which, ranging E. along the Conyngham Valley north of the Buck Mountain, penetrates the table-land of the coal-basins by the long Red Shale cove S. of the East Green Mountain. A continuous belt of the Red-Shale rocks extends from the Cove eastward, between Buck Mountain and Green Mountain, into the anticlinal valley of Swamp Creek, but whether lifted by the one axis of the Conyngham Valley, or met by another coming in Westward from the Lehigh, is a matter which must remain for the present in doubt. This anticlinal is nowhere saddled either by Coal-measures or the conglomerate.

Coal-Basin No. 5, or that of Little Black Creek and Main Black Creek.—The next basin encountered in our progress Northward is a long and narrow synclinal belt of Coal-measures, extending from East Buck Mountain, east of Buck Mountain Creek, to West Buck Mountain, west of the deep defile by which Black Creek passes Northward out from the table-land. The Eastern half of this trough lies chiefly in the valley of Little Black Creek, and is sometimes called the Little Black Creek Basin. The Western half, from the entrance of Cranberry into Black Creek, occupies the valley of this latter stream the whole way to West Buck Mountain, heading Westward near the source of Robert's Creek. It is doubtful whether the E. and W. basins of this belt are actually united, though they belong strictly to one synclinal wave. It would seem rather, in the present imperfectly-developed state of the district, that the Coal-measures have been all denuded from out of the trough or basin above the junction of Big Black Creek and Cranberry.

Next its E. end the Little Black Creek Basin subdivides, an anticlinal upthrow of the conglomerate breaking it into two branches; one running towards the main Southern spur of East Buck Mountain, the other keeping a more Northern course towards the N. synclinal spur of the same range.

Coal-Basin No. 6, or that of East Green Mountain.—Between the anticlinal last mentioned, or that of the Conyngham Valley, and another axis situated in the valley of the Nescopec and Oley creeks, occurs the almost detached coal-field of the East Green Mountain. This embraces two distinct coal-basins, separated by a local anticlinal, which lifts the upper strata of the Red-shale formation to the summit of the mountain. The larger of these basins occupies the W. half of the Green Mountain, while the smaller, lying about one mile N. of the E. point of this main one, is seated just at the N. edge of the table-land, where it overlooks the valley of Oley Creek.

Coal-Basin No. 7, or that of McAuley's Mountain.—In apparently the same general range or belt with the Western Green Mountain Basin, lies the remote insulated flat-topped mountain-basin of McAuley's Mountain. Whether this is situated between the same anticlinals which enclose the coal-basins of the East Green Mountain, I am not prepared to say, and therefore deem it wisest, for the sake of avoiding errors of classification, to rank it separately. The limits of the coal in this basin will be defined in a future chapter.

Sugar-Loaf Knob.—Nearly in the same general synclinal belt with the East Green Mountain, and McAuley's Mountain coal-basins, and just about midway between them, stands the Sugar-Loaf Knob, an oval conical synclinal hill, the mere peak or summit of which is capped, and protected by the hard lower beds of the Seral conglomerate. It contains no Coal-measures, but is interesting from its position in the line of the N. range of basins, showing as it does so unequivocally the prodigious devastation which the coal-rocks have undergone throughout all this district of country. The oval form of this hill is suggestive of its synclinal structure, its longer axis coinciding with the strike of the anticlinal and synclinal lines of the region.

CHAPTER II.

THE BEAVER MEADOW, OR SOUTHERN BASIN OF THE EAST MIDDLE COAL-FIELDS, OR COAL BASIN No. 1.

This complex synclinal belt, already defined as lying between the Red Shale range South of the Spring Mountain and the main anticlinal of Pismire Ridge, embraces several closely-connected subordinate coal-basins, or more properly one irregular basin undulated by several anticlinal waves into three connected troughs. These range from a little E. of the Mauch Chunk and Berwick Turnpike to the head-waters of the Catawissa Creek; the greatest length of the belt of Coal-measures being about 7 miles. One mile or a little more will express the average breadth of the coal-field from Beaver Meadow westward to the French village, though from Jeanesville to the latter point the two limits of the coal are about $1\frac{1}{4}$ miles asunder. The E. end of the general basins separates into two prongs or subdivisions, the more Southern and longer one occupying the valley of the main Beaver Creek south of the S. crest of Pismire Ridge, and extending apparently for half a mile E. of the village of Beaver Meadow; the more Northern branch heading a third of a mile Eastward of the turnpike in the table-land N. of the South Pismire Ridge and the main N. anticlinal of that range. The N. portion of this coal-field breaks, on the other hand, into three lesser basins, the centre one being by far the widest and longest. Of these, the most Southern, or the basin of South Beaver Creek, running forward past the German village, terminates, so far as the Coal-measures are regarded, about 1 mile nearly S. of the French Company's old sawmill. The middle and largest trough heads Westward towards the synclinal knob S. of Panther Run (?) somewhere upon that table-land, perhaps $1\frac{1}{2}$ miles S.W. of the above-mentioned sawmill. And thirdly, the most Northern of the three lesser basins appears to have its W. end between the French village and the sawmill, about three-quarters of a mile from the former.

ANTICLINAL UNDULATIONS OF THE BEAVER MEADOW COAL-FIELD.

Two sets of anticlinals undulate and disturb the general Beaver Meadow basin, the one belonging to a group of important undulations traceable Westward from the Lehigh; the other, to two or more leading axes entering Eastward from the Red-shale district of the Catawissa Valley.

Eastern Anticlinals of the Coal-field—Anticlinal Axis A.—The principal Eastern axis A, passing through the S. crest of the Pismire Hill north of Beaver Meadow village, and through the Beaver Meadow Mines, follows the valley of West Beaver Creek, and dies out under the village of Jeanesville. This lifts the conglomerate into view on the turnpike a little S. of the Catholic church; it forms the nearly perpendicular N. dip in the centre of the old Beaver Meadow Mine, and carries this N. or perpendicular dip along the valley of West Beaver Creek to the Jeanesville Colliery No. 1, where, by the dying down of the axis, the large coal thus lifted turns suddenly S., and saddles itself, basining again between this axis and the anticlinals next S. of it.

The Old Open Cut Mine of the large Beaver Meadow coal-bed was wrought upon the back of this anticlinal. Slope No. 4 is likewise situated upon it. Near this last-named colliery, the denudation which cut the valley of the West Beaver Creek, sweeping away the large coal from the anticlinal axis, has caused its S. and N. outcrops slightly to diverge; the S. outcrop taking the foot of the hill S. of West Beaver Creek and of the railroad, until it approaches the N. descending ravine half a mile E. of Jeanesville. Before reaching this point, the denudation of the measures at the ravine has swept away the Big Coal, causing its basin to terminate there.

Anticlinal Axis B.—S. of the anticlinal we have just traced, there ranges another which, entering the Coal-measures N. of Beaver Meadow village, in the broad S. shoulder of the Pismire Hill, passes Southward of the outcrop of the great coal-bed of the Old Beaver Meadow Mines, forming the Southernmost of the two nearly perpendicular N. dips which undulate that mass of coal. It is this axis apparently which courses N. of the Colerain Colliery Breaker, and through the N. side of the flat-topped hill, over which runs the Beaver Meadow and Tresckow Road, and which appears just S. of the tunnel on the Wharton Vein, in the ravine or hollow half a mile S.E. of Jeanesville. This axis probably expires in the South Jeanesville Basin, more correctly the middle trough of the coal-field, somewhere near or W. of the Tamaqua Turnpike. Throughout its range it is nowhere oversaddled by the Great Coal-seam, but lifts the next lower measures to the surface, the point of nearest approach of the outcrops of the large coal-bed being just N. of the summit of the high flat knob containing the flattest S. dips of this anticlinal.

Sub-Basin A, *or that of Axes* A B.—The E. extremity of this basin is a mere flat synclinal table at the S. foot of the conglomerate N. of Beaver Meadow village, and deeply denuded of its Coal-measures at the head of the Sand Spring ravine. It contains none of the Big Coal until we go about a quarter of a mile W. of the turnpike; there the basin receives the E. end of the S. trough of the large coal of the Beaver Meadow Mine, the outcrop of this coal being discernible a little E. of Ratcliff's New Slope, on the railroad leading to his Breaker. Contracted at the passage of West Beaver Creek across the basin, the Big Coal expands in the trough again W. of the stream and the railroad, and forms there a trough between the base and the brow of the hill, terminating by denudation, as already intimated, E. of the next W. ravine. The lower Coal-measures of course are not thus circumscribed in the basin, but extend from one bounding anticlinal to the other. It is within this basin at its W. extremity, or near the Tamaqua Road, that a small anticlinal undulation intrudes itself almost on the parallel of the old colliery in the ravine, and S. of the main W. anticlinal which separates the Big Coal into two outcrops at Jeanesville Colliery No. 2. This short subordinate anticlinal, by throwing out the large coal into diverging outcrops E. of the turnpike and in the ravine, conspires, with the previously-traced axis B, or that of the Wharton Vein Tunnel, to cut off the large coal E. of the ravine entirely from that W. of it. It furthermore, by lapping past the E. point of the main axis—that of Slope N. 2—causes the middle basin, or that S. of the axis, to swing its outcrop of the large coal, and the mine gangways upon it, abruptly Southward near the turnpike.

Anticlinal Axis C.—A small anticlinal flexure, parallel with that last traced, and, like it, passing through the shoulder of Pismire Hill just N. of Beaver Meadow village, crosses the ravine of the Sand Spring and that of West Beaver Creek, and shows itself on the road just at

Colerain. It is probably this roll of the strata which disturbs the course of the gangways in the W. end of the Cleaver or Ratcliff Mine.

Basin b.—No defined basin is traceable between the anticlinals B and C from N. of Beaver Meadow to Colerain, the data being too imperfect; but the undulated dipping of the lower Coal-measures W. of Beaver Meadow intimates that this basin is present even there; but W. of Colerain we see it unequivocally exhibited in the flat synclinal hill over which the main road passes. Here there occurs a small insulated patch of the large coal-seam, scarcely covered by a sufficient thickness of strata to admit of being profitably mined. On its N. edge this little basin of the Big Coal shows a S. dip of 30°; but this quickly flattens, and there is scarcely any decided N. dip belonging to the anticlinal C to the S. of it.

Other undulations seem to occur between the crest of Pismire Hill and the N. edge of the meadows of Beaver Meadow Valley, but the ground is altogether too obscure to permit our tracing them with any clearness. They undulate the lower Coal-measures N. and W. of Beaver Meadow village, and will greatly interfere with the successful mining of the one or two otherwise workable coal-seams of that neighbourhood.

Anticlinal Axis D.—A fourth regularly traceable E. axis, situated to the N. of the main saddle A of the Pismire Hill, emerges W. from the N. side of that ridge, crosses the turnpike not far from the Catholic church, and descends into the valley of North Beaver Creek. On the S. edge of this little valley it exposes, at Slope No. 8 of the Beaver Meadow Mines, a regular broad saddle of the large coal-bed. About one-fourth of a mile further W., it passes N. of the Old Slope No. 1, and beyond this it gradually flattens away or expires in the North Beaver Meadow Basin, or North Jeanesville Basin, somewhere S. or W. of Slope No. 7. This anticlinal, therefore, divides the North Beaver Meadow Basin into two branches at Slope No. 8, the S. branch being the N. basin of the old mines, and the N. branch, the separate narrow trough of the Big Coal, following the valley of North Beaver Creek from that point to the neighbourhood of the old tavern on the turnpike.

Basins of Axes A *to* D, *and of* D, *and of Main Axis No.* 1.—Little need be said in addition to what has just been stated of the two basins separated at Slope No. 8 by the intermediate axis D. The E. outcrop of the large coal of the old mines, in the more S. of these two branch-basins, approaches within about a fourth of a mile of the turnpike; while the same thick seam in the trough next N. almost reaches to the road. Thus all the three branch-basins of the large coal, the two of the old mines, and that of North Beaver Creek, terminate very nearly on the same meridian, or the same N. and S. line.

WESTERN ANTICLINALS OF THE BEAVER MEADOW COAL-FIELD.

In the W. half of the general synclinal belt embraced between the leading anticlinals Nos. 1 and 2, there enter the coal-field from the W. at least two separate anticlinal axes, which, with the N. dip from Spring Mountain, and the S. one from the anticlinal of Pismire Ridge, form the three branches into which the general coal-basin divides itself W.

The most Southern of these anticlinals, which we shall designate by the letter E, issuing from the Red-shale country of the Catawissa, enters the table-land of the coal strata by the hollow which divides the W. end of the Spring Mountain into two knobs. Passing thence across the head-waters of a S. tributary of the Catawissa, where denudation lays bare the Red Shale, elsewhere covered on the back of the anticlinal wave by the conglomerate and the Coal-measures, as already indicated, the axis is saddled by the coal-rocks about a mile S. or S.E. of the French Company's old water-driven sawmill. From this point E. to the Tamaqua Turnpike, and indeed to the Tresckow and Beaver Meadow Road, the line of this saddle is plainly indicated by a swell of the ground, dividing the valley of the South Beaver Meadow from the head stream of the Catawissa on the W., and the waters of West Beaver Creek on the E. At the source of the Catawissa, or one mile W. of the turnpike, this anticlinal axis, accurately determined in position by shaftings for coal on the York Company's land, lies just 3200 feet S. of that company's Slope Colliery No. 1. At the turnpike it lies a few hundred feet N. of the Tresckow Hotel, and on the road thence to Beaver Meadow its intersection with this latter road is about 3000 feet E. of Tresckow, and apparently just N. of a shaft and boring undertaken by the German Company in quest of the large coal. Further E. than this point it is not at present traceable.

Coal Measures on Axis E.—From the point on this saddle S. of the French sawmill, where the lowest of the coal strata first roll over the conglomerate, all the way to its point of disappearance Eastward, it would appear to be nowhere overarched by the large coal, or that of the Old Beaver Meadow Mines, but to be overlapped only by the underlying Coal-measures. At the shafting S. of the York Company's Slope, the two coal-beds next beneath the Big Seam are alone made to outcrop on the opposite sides of this axis. The lowest of these coals, just adjoining the anticlinal line, measured, it is said by those who did the shafting, 9 feet in thickness upon both outcrops. The other, or that which next underlies the large bed, measures, according to the same good authority, 8 feet in thickness also on both its outcrops.

Further E. along the axis, it would seem that the denudation E. of the Tamaqua Turnpike, or N. of Tresckow village, has laid naked a third underlying coal, or one next inferior in position to that opened at the axis further W. At Tresckow these three veins are severally 5 or 6 feet, 4 feet, or 4½ and 8 feet in thickness. The occurrence of coal so low in the series, so far E. as the road from Tresckow to Beaver Meadow, militates strongly against the probability that the German Company will find the large coal upon their estate either N. or S. of this axis. Our cross section of the district will show that the three lower coals, here described, occupy the whole N. side of the valley of Beaver Creek, even to the stream itself; and it is impossible to conceive that the great or thick bed can find room to basin above them in the centre of the valley, where the dip of the strata is known to be nearly horizontal. The only possible condition under which the large coal can occur on the German property, is as a bed beneath, and not above, the three smaller seams indicated in the Section; but these are almost certainly the lower coals, or those next above the conglomerate, as may be seen by noting the close proximity of that rock to the S. edge of the bed of the valley at Tresckow, and its gentle Northward dip there, conditions which almost preclude the admission of any such series of coals as the hypothesis of the presence of the large bed beneath these three of the section would imply. The exclusion of the large coal from the anticlinal N. of Tresckow may be considered as furthermore demonstrated when we trace the uppermost of the three beds at Tresckow from its place in the bed of the South basin, continuously by the bench it forms and the shaftings made upon it, to the Slope Colliery seated upon it W. of the road, and thence again to the shaftings one mile further W., and there identify this South-dipping seam with the 8-feet-thick bed on the N. side of the axis, seen dipping unequivocally N. below the S. outcrop of the Big Vein in the Middle or York Company's Basin. The amount of uplift at this anticlinal, and the deep and wasting denudation of the strata along the whole line of the valley of South Beaver Creek, have left this basin apparently without a trace of the large Beaver Meadow coal-bed. If a narrow strip of it does exist, it can only be under the marsh or Beaver Meadow opposite the town, and perhaps for a mile W.; but that even such is the case seems to me quite improbable.

Basin c, or that of South Beaver Creek.—Little need be said in addition to the observations just made respecting the coal contained in the South Beaver Meadow Basin, or that which, further W., is the basin of the German Company. It has been already stated that the Eastern termination of the coal in this trough is a little E. of Beaver Meadow village, and that from E. of Tresckow, Westward to the end of the basin, none but the two or three lowermost coal-beds lie within it. What remains to be said, relates to the more central part of its range, or that of the neighbourhood of Colerain. A little E. of this place is the old and now suspended colliery, No. 3 of the Beaver Meadow Company, wrought in a South-dipping bed of coal some 9 feet in thickness, demonstrably a lower coal than the large vein of the Beaver Meadow Mines. This is, in other words, the Wharton Slope upon the Wharton Vein, generally admitted to be the next under the Big Coal. Half a mile to the W. of this slope occurs the Eastern extremity of a Southward-sloping basin of the Big Coal bed, lying between the Beaver Creek Valley and the Beaver Meadow and Tresckow Road, and capped at this E. end by Cleaver's (now Ratcliff's) Mine-drifts. This basin of the Big Coal I regard as resting in the trough between axes B and C of the hill N. of it, and the Eastern prolongation of the Northern axis C, or that just N. of Tresckow; and I conceive that the influence of this last-named anticlinal is to exclude the large vein entirely from the neighbouring valley of the South Beaver Meadow Basin. The gradual subsidence Westward of the small axis C, or that N. of the Wharton Slope, allowed a sufficient depression or synclinal trough between the two saddles B and C to preserve from total destruction, by denudation, this small narrow basin of the large coal now wrought by Ratcliff.

Fig. 204.—Wharton Creek E. of Jeanesville.

Anticlinal Axis F, *or that of Jeanesville.*—The more Northern of the two anticlinals which penetrate the Beaver Meadow Coal-field from the W. is one apparently of great length and straightness. Terminating as already indicated just at Jeanesville, it comes Eastward from the Red Shale Valley of the Catawissa, following the main creek to a mill, and thence the same valley — no longer occupied by the creek, however — to Clark's. It crosses the Catawissa higher up, near the mouth of Panther (?) Run, from which it pursues the valley of this tributary until it once more intersects the Catawissa, now near its source, at the old sawmill of the French Company, 2¼ miles W. of Jeanesville. About half a mile E. of the sawmill, the Coal-measures seem for the first time to saddle themselves across the anticlinal axis; first, only the lowest coal-beds, and opposite the French village, the highest of this inferior group, or the seam next beneath the large one. It is not until we approach the position of the Jeanesville Slope, No. 2, that the large seam unites its two outcrops to arch itself at the anticlinal axis. This saddle appears to die out altogether a few hundred feet E. of the turnpike at Jeanesville, the workings in Mr Milnes' Colliery proving that it expires in the basin S. of his old slope, No. 1.

Basin C, *or that of the York Company, and the Jeanesville South Slope Mine.*—Between the two principal Western anticlinals E and F is embraced by far the largest of the Western basins of the Beaver Meadow Coal-field. Commencing our description of it at the ravine S.E. of

Jeanesville, where several of the smaller Eastern anticlinals break it up, and tracing it to its Western termination in the Powell Lands, it has a length of probably 4½ miles. Its breadth at the widest place, or where the Coal-measures saddle both its bounding anticlinals—namely, opposite the French village, and for a short distance Westward—is about 3700 feet. From a little West of the turnpike to its Western limit, this basin, so far as we know it from the hitherto imperfect developments made within it, is a simple synclinal trough, without any included saddles, of serious magnitude at least, to undulate its strata. The highest coal-seam which it contains is apparently the one which next overlies the large bed—in other words, the fifth ascending of the series as at present ascertained. The only place at which this coal has hitherto been opened is on the York Company's ground, 2000 feet S. of the French village; it is nearly in the centre of the basin. How far this ranges E. and W. is not known. Both the N. and S. dips are very gentle, or only 10° or 12°, but at the foot of the slope the dip is 24°.

Extent of the Big Coal in the Middle Basin.—Venturing now upon an approximate tracing of the limits of the large coal-bed, we find the basin, as already stated, cut off by the ravine E. of the turnpike near Jeanesville, so that in this direction the E. outcrop does not lie 1500 feet E. of the road. The N. outcrop of the Big Coal follows the N. main anticlinal from Jeanesville No. 2 Slope to a point nearly 2000 feet S.W. of the French village. There it leaves the vicinity of the anticlinal axis to range more towards the S.W., converging to meet the S. outcrop, running more nearly Westward. It is impossible, in the present unexplored condition of the ground, to state within a mile or more where the W. end of the basin of the Big Coal actually is; possibly it terminates within about a mile W. of the York Company's Slope No. 1; that is to say, a little E. of the denuded valley by which the stream draining this basin passes Northward to the Catawissa. Possibly also it extends for one mile Westward of this stream, or just into the Powell Lands; but if it does, the basin can have no profitable breadth or depth, for some coal-shaftings recently made show that nearly the whole breadth of the basin is occupied by the three lower coals. The total breadth of the belt of the Coal-measures at this point, the E. end of the Powell Lands, is about 1000 feet—a narrowness which almost necessarily excludes, even with a steeper dip, the large coal of the middle of the basin.

Respecting the W. limits of the lower Coal-measures—or, in other words, the W. extension of the trough formed by the upper beds of the Seral conglomerate—too little is known to permit me to venture more than a mere conjecture, founded on the topographical features of the ground. I think it probable that the two margins of the lowest productive Coal-measures, converging from the anticlinal bounding the basin, the Northern from about half a mile W. of the village, the Southern from about as far W., finally meet and form the end of their trough or basin about 2 miles W. of the French Company's old sawmill, or one mile within the Powell Lands. Possibly the coal strata may extend one-third of a mile further Westward into the highest summit of the broad synclinal knob in which the conglomerate of this belt terminates; but the exact determination of the W. confines of the coal can only be reached by patient and systematic shafting.

Jeanesville Slopes.—In the vicinity of Jeanesville there are three slope-mines entering the Big Coal. The slope E. of the town descends at an angle of about 12° Southward. About 75 feet N. of the tip of the slope the measures descend upon a nearly perpendicular N. dip, and 300 feet N. of the slope the coal is cut in a perpendicular shaft. The coal crops out on the N. side of the basin about 500 feet N. of the shaft. This sharp anticlinal roll seems to decline rapidly going Westward, and will cause a deflection Southward of the gangways. The coal is also worked from a shallow basin S. of the foot of the slope, and over a saddle into S. dips again.

West of the town about 1000 feet are two slopes on the contrary dips of an anticlinal over which the coal is laid bare in an open cut. This roll seems to decline Eastward, for the coal cannot be traced beyond the slope E. of the village. If this be the case, it will affect the direction of the gangways driven Eastward. The dip on the N. side of the axis at the slope is 25°, at the top steepening to 45°. In the S. it is from 25° to 30°.

In the open-cut the following measurements of the Big Coal were taken :—

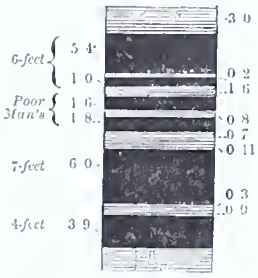


FIG. 205.—Big Coal, Jeanesville, at "Open Cut."

		Feet.	Inches.
	Slate and bony coal,	3	0
6-feet bench	Coal, good,	5	4
	Bony coal,	0	2
	Coal, good,	1	0
	Coal, bony,	1	6
	Slate,	0	2
	Coal, impure,	1	6
	Slate,	0	8
Poor Man's—	Coal, very good,	1	8
	Slate, fissile,	0	7
7-feet bench	Coal, bony and slaty,	0	11
	Coal, good,	6	0
	Slate,	0	3
4-feet bench	Coal, bony,	0	9
	Coal,	3	9
	Slate,	...	

The divisions of the large bed are nearly constant. At the Beaver Meadow Mine the Section reads as follows :—

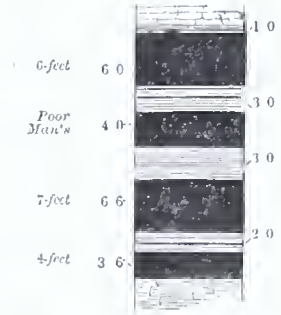


FIG. 206.—Big Coal, Beaver Meadows.

Rock cover,	...
Bone, 1 foot,	1 foot.
The 6-feet bench,	6 feet.
Coal, and slate, and bone,	3 ,,
Poor Man's Coal,	4 ,,
Coal, and bone, and slate,	3 ,,
The 7-feet bench,	6½ feet of coal.
Bone and slate,	2 feet.
The lower 4-feet averages,	3½ feet of coal.

JEANESVILLE.

Coal and slate worked together (of which 2 feet 3 inches is coal),	14 feet.
The 7-feet coal,	7 feet.
Slate,	½ foot.
The lower 4-feet bed has	5 feet of coal.

Shaftings on the North York Company's W. tract, beginning on the N. side of the basin :—

1st. A shaft about 300 feet S.; conglomerate; coal and coal-dirt, 5½ feet; bottom of fireclay, with *Stigmaria;* S. dip 35°. Forty yards S. of this first is the

2d Coal, 4 feet thick; fireclay bottom, with *Stigmaria;* S. dip 35°; then it is about 20 yards to the

3d coal, shafted to 7 feet of coal and dirt. It is about 45 yards to the

4th coal. It showed 6 inches of coal, with black dirt and slate.

North Beaver Meadow Basin, or Basin g.—The Northern division of the Beaver Meadow Coal-field, or that which receives the South-dipping strata of the S. flank of Pismire Ridge (not Pismire Hill, N. of Beaver Meadow village), is bounded, as we have already seen, by the anticlinal axis A from the Beaver Meadow Turnpike to the Jeanesville Slope No. 1, while Westward from Jeanesville it is bounded Southward by another anticlinal F, not strictly in prolongation with A, but a little S. of it. This basin towards it E. end is divided into two short branches by the intruding axis D: its W. portion, on the other hand, is enlarged at Jeanesville by the dying-out of axis A, and by the rising of axis F further Southward.

Limits of the Big Coal in the North Beaver Meadow Basin.—The S. limit of the Big Coal in this basin coincides very nearly with these two anticlinals D and F, until we pass a little distance W. of Jeanesville. There the outcrop of the Big Coal, running Westward, diverges from the anticlinal F, and when within from 1000 to 2000 feet of the French village, it terminates or swings round, and joins the N. outcrop. This Northern limit of the large coal, commencing a little W. of the Beaver Meadow Turnpike, and ranging first South-westward, passes slope No. 7 of the Beaver Meadow Mines, beyond which it takes a somewhat more Westerly direction, until within one-fourth of a mile of the Wilkesbarre Road at Jeanesville. It crosses the railroad, intersecting the turnpike about 400 feet N. of the creek in Jeanesville. This outcrop very gradually curves more and more Southward in the direction of the French village, until it meets the S. edge of the coal already traced, somewhere in the space above mentioned E. of the French settlement, and in the neighbourhood of the York Company's Branch Railroad. Upon this view of the W. limit of this valuable basin of the large coal, it scarcely enters the French Company's lands. The total of the trough thus assigned to it is a little less than 3 miles.

The Eastern and Western limits of the lower Coal-measures belonging to this North Beaver Meadow Basin have been already indicated; the first was stated to occur within half a mile E. of the Beaver Meadow Turnpike, and the last about three-fourths of a mile W. of the French village.

Dreck Creek Coal Basin, or Basin No. 2.—Very few particulars can be given respecting either the precise limits or the contents of this comparatively unimportant belt of Coal-measures. Lying on the N. slope of Pismire Ridge far Westward in the shallow valley of Dreck Creek and its Westward extension, this strip of the coal-rocks would seem to embrace no portion of the large or Hazleton Coal-bed, but only some of the underlying Coal-measures. The valley seems to be denuded of even these strata everywhere Eastward of a point less than 2 miles E. of the Berwick Turnpike. How far Westward they actually continue in the basin is a point not ascertained, the acknowledged absence of the large coal having withheld inducement to any artificial trials in quest of such coal-beds as may exist. True coal-rocks seem to extend, however, along the N. side of Pismire Ridge nearly to Cross Run, or opposite the Eagle Swamp. A coal-bed, probably the lowest in the series, has been opened in the basin by shaftings, but the coal was not fully proved.

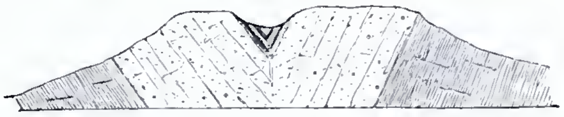


FIG. 207.—East End of Spring Mountain.

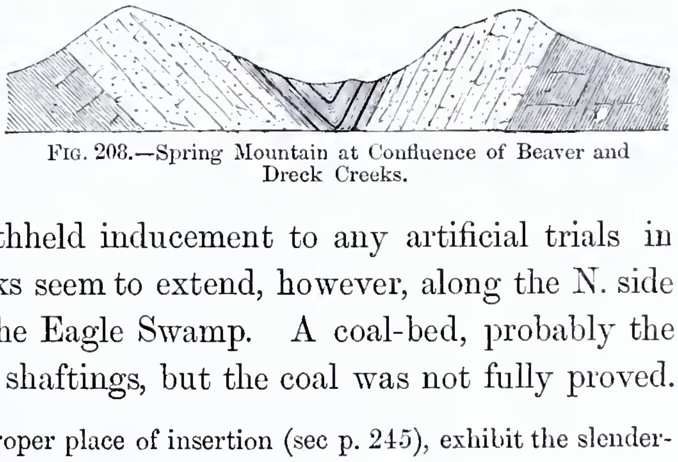


FIG. 208.—Spring Mountain at Confluence of Beaver and Dreck Creeks.

Note.—The above two cuts (figs. 207, 208) omitted at the proper place of insertion (see p. 245), exhibit the slenderness and closely-folded structure of the South Beaver Meadow, or Spring Mountain Basin, towards its E. end. The Coal-measures displayed are not productive.

CHAPTER III.

THE HAZLETON BASIN AND ITS BRANCHES, OR BASIN No. 3.

It has been already stated, in our general account of this basin, that it forks both Eastward and Westward through the intrusion of subordinate anticlinals. It is expedient that we indicate the position and the effects of these, as essential to a clear understanding of the limits of its coal strata.

ANTICLINALS H AND J.

Turning our attention first to the E. extremity of this coal-field, an anticlinal axis, H of the Map, ranges through the middle of the East Pismire Hill in the Buck Mountain Company's estate, dividing the Southern coal-field of that Company into two basins—their Basins No. 1 and 2, or H and I of our nomenclature. (See Cut, fig. 209.)

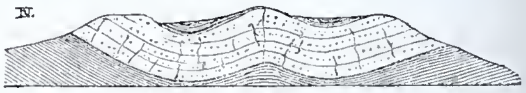


Fig. 209.—Buck Mountain Basins, East Pismire Hill.

The effect of this saddle is barely to separate the Large Buck Mountain Coal of these basins into two outcrops, which at their nearest approximation almost unite upon the axis. Between these basins the anticlinal wave is comparatively of gentle curvature, but W. of the termination of the smallest, or Southern basin, the dips upon its two sides grow steeper; that of the S. edge of the Northern, or basin I, being as sharp as 45°.

Another anticlinal, J of the Map, lies directly in the range of this axis H, and in all probability is but the W. prolongation of it; and my only reason for not designating them upon the Map as one axis is, that the intervening country being obscure as respects the dips, and there being little or no coal in it to incite to any explorations by digging, the actual continuity of the anticlinal has not been yet established.

This anticlinal J divides the E. extremity of the proper Hazleton Coal Basin into two short and broad, but shallow branches, the S. one, or that of the Board Yard on Hazle Creek, being seemingly the longest. As far W. as the road leading N. from the Board Yard to Jeddo, this anticlinal is overspread by very gently-dipping beds of the conglomerate; but a little further W. the lower Coal-measures probably close over the axis. The effect of this saddle, thus opposing itself to the E. prolongation of the Hazleton Basin, has been to lift out the Coal-measures, or to expose all but the very lowest of their strata to a wasteful denudation. The mere flattening-up of the bottom of the basin in Hazle Creek at the W. subsidence of this saddle, has had the effect, of course, of exposing to removal the whole of the upper Coal-measures, with the Big Coal included. This axis is traceable to within one-third of a mile E. of Stockton Colliery.

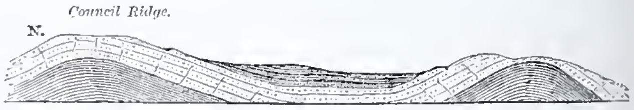


Fig. 210.—Section one mile East of Hazleton.

Basin h, or No. 1 of the Buck Mountain Company's Lands.—This small basin of the Buck Mountain Coal, now nearly wrought out, lies on the S. summit of East Pismire Hill, just E. of the Conyngham Road. The basin, tapering to a narrow point E., has had all the coal removed from its broader W. end. It is a symmetrical little trough of the large coal, the N. and S. dips being nearly equal, and about 25°; its length is about three-fourths of a mile. This Buck Mountain Company's coal-bed is here evidently the lowest productive seam of the series. It lies only a short distance above the conglomerate, and there are no traces of any other coal-bed underlying it. Nevertheless, it is by many persons regarded as the equivalent of the great Coal-seam of the Hazleton Basin, the chief reasons alleged being that the coal itself is too pure for either of the lowest or underlying seams; and moreover, that it contains the same three benches into which that thick mass is invariably subdivided. I cannot, however, adopt this view for the following reasons. In the first place, it implies too abrupt a change in the Coal-measures, for it assumes that nearly all the strata between the conglomerate and the great coal—that is to say, three beds of coal and their three thick overlying masses of strata, ponderous conglomeritic sandstones chiefly—should all vanish on account of an original deficiency of material, within the short space of 5 miles from where we know the series to be full and complete.

In the second place, it presupposes that the presence or the absence of the bird's-eye structure is a more permanent characteristic than it truly is, not considering that this is an accidental consequence of a peculiar stage of metamorphism, and not an inherent condition belonging to special beds of coal throughout their whole extension. That this bird's-eye fracture, so usually accompanied by thin perpendicular scales, or pellicles of pure white silica in the little fissures, is not an original feature of the coal, but a superinduced one, is manifest, from the fact of its crossing or cutting, and not coinciding with, the lamination or plates of deposit of the coal. It has evidently been introduced long subsequently to the deposition of the coal-beds at the period of their upheaval, consolidation, and metamorphism.

The argument asserting the identity of the Buck Mountain Coal with the large Hazleton Bed, from a correspondence between the two as respects their benches, overlooks the fact that at various points both in the Hazleton and the Beaver Meadow coal-fields, the lowest coal of the series is similarly compounded, and made up of three separate layers or benches, as may be seen by consulting the statements made respecting it in these Chapters.

Basin i, or No. 2 of the Buck Mountain Company.—This basin commences somewhere within one mile E. of the Conyngham Road, and just N. of basin *h*. Its W. termination, not yet established, is a little W. of the West line of that Company's lands, or about 2 miles N.E. from the Board Yard. Its greatest breadth opposite the New Slope, from outcrop to outcrop of the Big Coal, is from 800 to 900 feet, and here the dip of the strata is on both sides about 45°. Notwithstanding the seeming regularity, there occurs within the basin an anticlinal roll, the coal-bed being lifted in a saddle just in front of the bottom of the mine slope. So abrupt an arrest to the further progress of the slope, required the cutting of a short tunnel across the saddle to intercept the main N. dip by which the coal descends into the bed of the basin.

Coal of the Buck Mountain Company's Basins.—This coal-bed, as already stated, is composed of three separate benches or seams, the dimensions of which are as follows :—

An upper bench, . .	9 feet thick . .	Good coal.
Slate, . . .	2 " " . .	...
A middle bench, . .	5 or 6 " " . .	Coal a little rough.
Slate, . . .	A thin parting. . .	...
A lower bench, . .	2 or 2 feet 6 inches. . .	Rough and bony coal.

Basin j, or that of the Board Yard.—Precisely how far to the E. this shallow Southern branch of the main basin ranges, is not at present known; but it ceases probably within 1½ miles E. of the Board Yard.

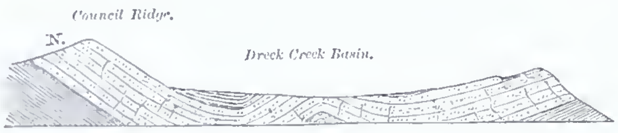


FIG. 211.—Hazleton Basin, E. of the Board Yard.

Towards the N. side of this trough a coal-bed has been proved a little S. of the conglomerate of the anticlinal, at a point about 300 yards N.E. of the Board Yard. The coal-seam reached at a depth of 17 feet, and dipping S. with a gentle angle, has a thickness of 6 feet 4 inches. It is a rough coal, with the ordinary bird's-eye fracture so common in the lowest coal-seams of this district. This is probably Coal No. 1 of the series. The width of the basin at this point, or to the S. outcrop of this same lowest coal near the railroad, is about 400 yards.

Another outcrop of a coal-bed has been caught by shafting at a point about half a mile W. of the Board Yard, near the railroad. Some persons have conjectured this to be the Main Hazleton Coal; but there is no actual evidence as yet that the large coal extends so far down the valley of Hazle Creek, no actual openings having been made upon it E. of the Stockton Mines.

Basin k.—The North Branch of the E. end of the Hazleton Basin is evidently a short and shallow recess from the main basin N. of the anticlinal J. Coal has been lately found in this basin a little W. of the road leading past its E. end to Jeddo. The bed, whose outcrop is not far S. of the North-bounding outcrop of conglomerate, has been reached by a shaft 18 feet deep, the top rock being a loose grey sandstone, somewhat pebbly. The coal, evidently the lowest of the series, has a total thickness of 9 feet. It consists of—

	Feet.	In.		Feet.	In.
A top bench, . . .	2	4	Slate, ...	0	6
Slate, ...	0	6	A bottom bench, . .	3	0
A middle bench, . .	2	6			

This coal is of medium quality, inferior to the great bed of Hazleton, but not the rough bird's-eye coal so generally characteristic of the lowest seams. The dip of the bottom slate being 60°, and of the top rock 45°, the coal-bed is evidently squeezed, and this is indicated by the slippery surfaces of the fragments.

Anticlinal M, *or that of Crystal Ridge.*—The next anticlinal which we meet with in our progress Westward is a short one, which belongs to the S. margin of the basin N. of Hazleton. It seems to originate somewhere E. of the Tamaqua Road in the lower Coal-measures S. of the outcrop of the great bed. Advancing Westward, it enters the area of the main seam, probably near the head-stream of Cranberry Creek. Within this interval it arches the Big Coal under the surface, and thus undulates it as far as Boyd's Run, beyond which the denudation having cut away the overlying strata, the Big Coal is at the Crystal Ridge Colliery, and for some distance E. of it, cut into two outcrops. Still further Westward, by the subsiding of the anticlinal, these two outcrops coalesce again, and the saddle which they once more form, droops, and finally expires in the valley of the South Hazleton Basin. The somewhat oblique course of this saddle to the strike of the coal, but especially its sinking Westward, causes the level gangways of the Laurel Hill Colliery, pushing Westward beyond Hazleton, to encounter first its N. flank, and finally its summit, compelling them to pause or turn.

Anticlinal N, *or that of Cranberry Ridge.*—The W. part of the Hazleton Basin is subdivided, as already mentioned, into two long branch basins, and the anticlinal which produces this forking is that of Cranberry Ridge, an irregular ridge saddled by the conglomerate from near the Cranberry Works westward. This axis, originating somewhere in the main Hazleton Basin W. of the town of Hazleton, first divides the Coal-measures, or lifts the conglomerate to the surface near the E. end of this Cranberry Ridge: one mile further Westward, the axis seeming to subside a little, the lower Coal-measures shut together over the line of the saddle for a short space, but presently divide once more into two outcrops going Westward, the Southern one diverging a little from the axis, and running forward to constitute the N. outcrop of the Tomhicken Basin; and the N. receding still more rapidly from it until it crosses the head-waters of Long Run, and reaches those of Stony Run, forming in this line the S. margin of the N. branch of the Hazleton Basin. This axis would seem to be the cause of the two opposite dips visible near the Cranberry Shaft. There is, however, within the mine S. of the shaft, a subordinate undulation or roll of the strata, but it is no part of the main anticlinal.

Anticlinal O, *or that of Tomhicken Ridge.*—Another anticlinal, that of Tomhicken Ridge, enters the Hazleton coal-field from the W. This penetrates the N. broad branch of the Hazleton Basin north of Long Run, but how far E. it prolongs itself cannot at present be ascertained. Being near its expiration, where it enters the Coal-measures N. of the sources of Long Run, its only effect seems to be to spread wider the lower Coal-measures in the Northern Branch Basin. It is probably owing to this anticlinal that the N. outcrop of the large coal-seam is cut away as it is at Cranberry village, and excluded from entering the Northern Branch Basin, or that of Cranberry Creek. Whether this large coal sets in again W. of Cranberry Creek, is a matter not positively determined, some shafting being now in progress near the E. line of the Powell Lands, with a view to ascertain this. If it does indeed exist there, it must be N. of the Tomhicken axis, and therefore considerably N. of Long Run, which flows first S. of, and then across, that anticlinal. My own view is, that the North Hazleton Basin on the Powell Lands is too shallow to contain any vestiges of the great coal-bed.

Basin N, *or that of Big Tomhicken.*—The Main Hazleton Basin bifurcating, as already mentioned, by the intrusion of the Cranberry Ridge anticlinal N, sends forward to the W. a long narrow branch basin, which we designate by the letter N. This containing the Big Hazleton coal-bed about as far as the entrance of the small run called Eagle Creek, carries thence for several miles only a narrow and shallow strip of the lower Coal-measures in the middle of the valley of the Big Tomhicken. The dips in the basin are very regular throughout, its length growing somewhat steeper as we advance Westward along it, but nowhere receding 45°. Two or three shafts have been sunk on coal in this basin, one on its S. edge $1\frac{3}{4}$ miles W. of the Powell Lands, where the coal dips 35° N., but its thickness is doubtful. Another shaft reaches coal about half a mile W. of the Powell line. Near the E. side of this large estate, or where the Phinney Road crosses the basin, there remains in it but a small amount of the lower Coal-measures; but Eastward again the basin widens and deepens, and at Eagle Creek it receives the W. extremity of the basin of the large Hazleton Coal-vein.

Basin O, *or North Branch of the Hazleton Basin.*—As already intimated, the Big Coal seam extends no further in the basin N. of the Cranberry Ridge axis than its outcrop at Cranberry village, unless, indeed, it enters it W. of Long Run, as an insulated patch penetrating perhaps a short way into the Powell Lands; but at present the evidence is insufficient to establish even this conjecture. The W. point of this basin is at the source of Stony Run north of the Horse Shoe Swamp, or some 4 miles W. of Cranberry. Here the basin seems to divide itself into two, one fork extending up Wolf Run, the other, and longer one, up Stony Run. North of the middle of this basin, and near the E. line of the Powell Lands, or the N.W. corner of the Kunkle Tract, two or three coal-beds have been carefully opened by shafting; one of them is alleged to have shown a thickness of 6 feet, and another of 8 feet of coal, and the dip is S. 30°. Other developments are now in progress.

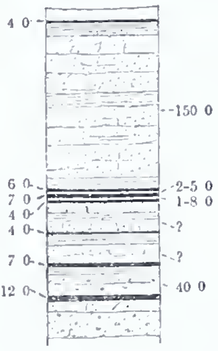


Fig. 212. — Coal Strata, Hazleton.

The Main Hazleton Coal Basin.—Restricting our attention now to the Main Hazleton Basin, to the exclusion of its Eastern and Western prolongations and branches, we may state it to have an average width, from outcrop to outcrop of its lowest coal, of nearly seven-eighths of a mile, being narrowest at the Stockton collieries, and widest opposite Crystal Ridge.

Of the lowest Coal-measures in this basin but few particulars present themselves claiming a permanent record here. There appear to be three coals underlying the Hazleton large seam. The *lowest* of these is usually the thickest and best in quality, though for the most part it is full of the bird's-eye fracture, and very rough. Near the Sugar Loaf Mine it has been proved 7 feet in thickness, outcropping at a gentle dip about 150 yards S. of the face of the conglomerate. Further W., and on the same N. side of the basin, it has been mined in a small gin-slope, exhibiting 11 feet of rough coal in three benches. Again, about 3 miles W. of Hazleton, it has been opened on the Kunkle Tract, in the N. branch of the Hazleton Basin, showing a thickness in the shaft of about 10 feet of rather rough coal. There it is close to the conglomerate, the dip being rather steep. On the S. side of this same basin it has been opened on a gentle N. dip, outcropping about 120 yards from the conglomerate, and showing the same thickness of 10 feet. Still further W., but in the S. or Tomhicken basin, it has been exposed by shafting, dipping N., and exhibiting a thickness of 15 feet, with three benches. Here the coal resembles somewhat that of the Hazleton bed. Yet further W., though still some 2 miles from the junction of South and Big Tomhicken, this coal proved, in a shaft on the N. slope of the Catawissa Ridge, to have a thickness of 9 (?) feet.

The *Second* coal ascending, or next in order, opened at the Laurel Hill Colliery, seems to possess there a thickness of 6 feet. It outcrops about 600 feet S. of the outcrop of the Big Coal, dipping at an angle of about 30°.

On the N. side of the basin, this coal outcrops N. of Hazleton in a well-marked bench about 1000 feet N. of the outcrop of the main bed. It has been reached by shafting in that neighbourhood near the Wilkesbarre Turnpike. This coal is usually from 5 to 7 feet in thickness, but it is generally a rough and bony coal.

The *Third* coal of the series, or that next beneath the great bed, outcrops on the N. side of the basin, at a gentle dip of 20°, about 500 feet from it. It also is indicated by a well-defined bench on the sides of the basin. This coal has been proved in but few places, but its usual thickness is known to be about 5 feet. In quality it is better than either of the two beds beneath it.

The *Fourth or Big Hazleton Coal Bed.*—The next in ascending order, the sole source of the mining wealth of the Hazleton Basin at the present time, is a complex mass, consisting of three main seams or benches of coal. These, and the dividing-slates which make up the total mass, some 27 feet in thickness, exhibit in the Laurel Hill Colliery of the S. side of the basin about the following average dimensions and subdivisions :—

The lowest bench of coal is 5 feet thick, but only 2½ or 3 feet of it are of prime quality, the remainder being rough bird's-eye coal.

The hard slate rock above this varies much in its thickness throughout the basin : it is thinnest on the N. side, as at Sugar Loaf and Hazleton No. 3 slope, but W. of Hazleton No. 1 slope it begins to enlarge, and 500 yards further it has swelled to 16 feet.

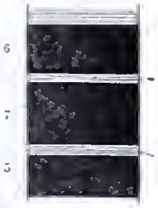


FIG. 213.—Big Coal of Hazleton—General Type.

The Seven-feet bench consists of good coal, though one band of it is rather coarse ; usually it is of the best quality on the N. side of the basin. This bench is, however, remarkable for consistency throughout the different mines.

The division above the Seven-feet bench, called by the miners "the benches," is an alternation of coal, bony coal, and slate, but it includes in some places a sufficient amount of pure coal to admit of mining, yielding even 4½ feet of coal, of a coarse quality.

The next or Six-feet bench has in some places a thickness of 8 feet, and in others not more than 3 or 4 feet. On the S. side of the basin, at Laurel Hill, this is a coarse coal, though marketable ; but in all the collieries on the N. side it is of excellent quality.

The top bench consists of slate and bone coal, with no marketable coal in it. Its average thickness is 4 or 5 feet. This is often left as the roof of the mine.

The immediately overlying rock is sometimes a rough sandy roof-slate 3 or 4 feet in thickness, and sometimes the coarse capping grey sandstone, without the intervening slate. This sandstone is a massive deposit many yards in thickness, and embraces, among its middle beds, some which are very pebbly or conglomeritic.

The *Fifth* coal, and uppermost in the basin, is a seam about 4 feet thick, lying at a considerable interval above the large bed. This, like the rest, is a White-Ash coal. It has been proved to approach very near to the surface in the centre of the basin, being lifted by an anticlinal undulation under the main street of the village of Hazleton, where its dips have been established in several wells and other excavations. The existence of this anticlinal is an intimation that the central or deeper tracts of the basin are not without important undulations.

HAZLETON.

The mines in the *Hazleton Basin* are as follows :—

Hazleton Slope No. 1 is sunk upon the Big Coal, dipping Southward 23°. Its length is 210 yards. From the foot of the slope, gangways are driven E. and W. upon the coal. In a similar manner, at higher levels, two gangways work out the coal. The extreme Eastern point reached in 1854 was 1100 yards : Westward the middle level was driven 900 yards. In the E. gangways the coal at times is somewhat soft and crushed. Between the lower benches of the Big Coal in this mine there are 2 feet of slate, which thickens up to 16 feet in the Western gangways, 500 yards from the slope.

Slope No. 3 of the Hazleton Company is situated on the N. side of the basin E. of Hazleton ; its length is 150 yards. The inclination near the surface is 23°, but it gradually steepens to 30°. Gangways are driven at two levels from this slope E. and W. Our measurements, representing the thickness of the Big Coal, are taken between this mine and Slope No. 1. They are as follows :—

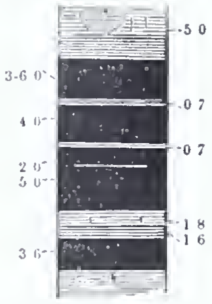


Fig. 214.—Big Coal, Hazleton.

		Feet.	Inches.
	Slate and Bone Coal,	5	0
Six-feet bench.—	Coal good,	3	6
	Black slate,	0	7
Poor Man's.—	Coal, fair quality,	4	0
	Slate,	0	7
Seven-feet bench	Coal, good,	2	0
	Coal, lower 10 inches, pyritous,	5	0
	Slate,	1	8
Four-feet bench	Coal, bony,	1	6
	Coal, good,	3	6

Sugar Loaf Slope, one mile E. of Hazleton; length 180 yards, and to be sunk 80 yards further. Two levels and gangways E. and W.—600 yards in the former direction, and 400 yards in the latter. The dip is about 28° S. The Big Coal retains its average dimensions.

On the S. side of the basin near Hazleton, the *Laurel Hill* Slope Mine, No. 2 of the Hazleton Company, is sunk 180 yards, at an inclination of 25° N. There are two levels, one 80 yards down, the other at the foot of the slope. The E. lower gangway sweeps round to the N., and turns W. to meet the W. gangways, which in like manner are deflected to run E. It thus appears that there is a small local basin, proved by the workings of this mine, which heads up E. and W. Its length is about 200 yards. The upper level gangway, going W., seems to be uninfluenced by the roll. It is $1\frac{1}{4}$ miles long, bearing S. 75° W. The breast of coal W. is 250 yards above this gangway; a counter-level was therefore needed in order to work off the coal. In this counter-level the coal was found to flatten W. of the road to Tamaqua, and it apparently arches over into a S. dip. The anticlinal thus indicated appears to expire to the W.

The *Crystal Ridge Slope* is situated S. of Hazleton upon the Big Coal, dipping S. 25° from a minor axis S. of that above alluded to. The basin is reached at 160 feet. This basin evidently rises in its course W., for the gangways in that direction incline for some distance. Coal is worked from the N. dips of this basin. These N. dips at first rise very rapidly from the basin, then grow flatter, and finally steepen at the outcrop. An upper level gangway is mined E. and W. from a point 50 yards down the slope of Crystal Ridge.

Cranberry Shaft, W. of Hazleton, is sunk 26 feet to the top of the Big Coal, and 40 feet to the gangway level. In driving the gangway W., a rock-fault was met between 600 and 700 yards from the shaft. The fault bears S.E. Coal was met again by going 30 feet through the fault. Its quality was found unimpaired. The dip in the gangway is S. at an angle of 20°; but in driving up the breasts some distance W. of the shaft the coal ran flat, and it was expected to turn over into a N. dip owing to the influence of an anticlinal. The coal-bed basins S. of the main gangway, and the branch gangways are deflected until they encounter the effects of a gentle roll, around which they again turn and follow their normal course W. A slope-mine enters upon the same great bed W. of the shaft to the level of the main gangway.

In the Hazleton Basin at Stockton, 2 miles E. of the village of Hazleton, are situated the mines of Packer, Carter, and Company.

The *Old Slope* No. 1 is sunk on the S. side of the basin upon the Big Coal bed. Its inclination, at first 45°, steepens to 58°. The slope length is 100 yards, and from it gangways are worked E. and W. to considerable distances. On the N. side of the Valley, Slope Mines Nos. 2 and 3 are dependent upon the same great bed, which retains its bulk and parting-slates as at Hazleton. In No. 2 the dip, at first 50°, flattens at the bottom to 30° or 35°, and in No. 3 it is 20°. In the same vicinity a water-level tunnel has been driven N. to the Big Coal, which is mined from it by gangways driven E. and W. The tunnel is 200 yards long. Before meeting the Big Seam two small beds of coal or coaly matter were struck, one at the mouth of the tunnel, the other 150 yards in. The dip in this mine is 20° S.

The New Horne Coal is on the small slope; the bed is 11 feet thick; it was worked for 7 feet, and the best bench of 4 feet was left beneath. On the lower bench was traced the same coal as on A. S. Roberts' land, 3 miles W.; it proved to be 10 feet thick, and good.

The Horne Coal is about 9 feet thick at Horne's; it is 100 feet S. of the turnpike. Mr Fenstermacher found it, and opened a coal 6 feet thick at Roberts', 3 miles W., which he regards as the same. The strike between it and the Four-feet Coal is similar, and the two benches showing the outcrops are nearly in a line: so the 4-feet is but an upper coal, probably the next adjacent.

LIMITS OF THE MAIN COAL-SEAM, AND THE COLLIERIES AT PRESENT ESTABLISHED ON IT IN THE HAZLETON BASIN.

Directing our attention now to the area occupied by the great coal-bed of the Hazleton Basin, we find that this has a length of from 5 to 5½ miles, and a maximum breadth W. of Hazleton of nearly three-fourths of a mile. East of Stockton, or Carter's Collieries, the two outcrops of the basin of this coal seem rapidly to approach each other, and to indicate its terminating at no great distance E., the extensive denudation of the Coal-measures in this part of the valley of Hazle Creek having tapered it off. From Carter's Slope No. 1, or the most Eastern working on the S. edge of the basin, the outcrop rapidly descends into the bed of the valley to meet the N. outcrop, gradually deflecting in the same manner, but precisely where they unite has never been ascertained. Tracing the S. outcrop W., it will be found to range in a nearly straight course, with a gentle undulation, influenced by the ravines which cut the N. slope of the hill against which it rests the whole way to the vicinity of Eagle Creek, a mile W. of the Crystal Ridge Mine. The N. outcrop, traced W. from Carter's newly-established mine, No. 3, observes likewise a very nearly straight direction till it approaches within a fourth of a mile of the Cranberry mining village. There, in the neighbourhood of the valley of Cranberry Creek, the upper strata have been extensively denuded, and the edge of this coal turns rapidly towards the S.W., to cross the creek in the direction of the Cranberry Mine Shaft. This coal, therefore, does not extend into the basin N. of the anticlinal axis of the Cranberry Ridge, but its N. outcrop, in its W. extension, belongs to the Southern Branch Basin, or the so-called Cranberry Basin. From the Cranberry Mines we may trace it therefore along the S. slope of the Cranberry Ridge to its W. termination, where it unites with the S. outcrop near the entrance of Eagle Creek into the valley.

Nine collieries are at present seated upon this valuable mass of coal. Three of these are on its S. outcrop—the Stockton Colliery, No. 1, belonging to Packer and Carter; the Laurel Hill Colliery, or No. 2 of the Hazleton Company, the W. gangways of which now extend for 1¼ miles W., passing far beyond the town of Hazleton; and, thirdly, the Crystal Ridge Colliery and Slope, working like the others, but descending S. into the local branch basin of the Crystal Ridge, the property of the Cranberry Company. Five of the remaining six are seated on the N. outcrop, Carter's New Mine No. 3, opposite the Stockton Mine No 1, being the most Eastern ; the Mine No. 2 of the same company, three-quarters of a mile W., being the next ; the Sugar Loaf Mine, half a mile W. of this, the third ; the Hazleton Company's Slope, No. 3, five-eighths of a mile still further W., the fourth ; and the Hazleton Old Slope, No. 1, 1$\frac{1}{8}$ miles yet further, being the fifth.

The ninth and last to be enumerated is the Cranberry Colliery, seated near the actual outcrop, as already mentioned, but near the anticlinal axis of the Cranberry Ridge, and therefore more nearly in line with the centre of the Hazleton Basin than with either margin of it.

Dips.—The configuration of this basin, or the more central part of it embracing the large coal-bed, will be understood when we state that the average degree of dip N., along the S. outcrop, is about 25°, until we approach it E. end, where it is as steep as 45°. The N. outcrop of the same coal exhibits at the various collieries S. dips varying from 20° to 30°, except at Carter's Slope No. 2, where the outcrop shows a steepness of nearly 50°. The N. side of the basin appears to flatten in descending towards the synclinal centre of the valley, whereas the curve steepens, at least in the Stockton Colliery, on the S. side. It has been already intimated that the centre of the basin is more or less undulated : that this must be the case is manifest from the positions occupied by the several known anticlinal flexures which observe directions likely to carry them a greater or less distance into the interior of the basin, and evidence has already been cited of the presence of a saddle quite in the middle of the trough under the village of Hazleton. Upon no other hypothesis than this, of a somewhat flat but undulated synclinal bed, can we explain the absence of a considerable series of coal-seams, such as should overlie the great bed, if the marginal dips into the basin should continue to any great depth. There being but one upper coal-bed detected, is a strong intimation that the strata overlying the main coal-seam in the middle of the trough are comparatively thin.

I estimate the total area of the great Hazleton bed at about 1700 acres. The basin is remarkably destitute of faults, or any disturbances which cause a waste of the coal in mining, and with due care it is practicable to abstract at least five-sixths of all this coal from the basin. The seam yields of merchantable coal a thickness varying from 15 to 17 feet, equivalent to a net product, with good mining, of 20,000 tons to the acre, a proportion which implies an aggregate of marketable coal in the basin of about 34,000,000 of tons.

CHAPTER IV.

BLACK CREEK BASINS.

BIG BLACK CREEK BASIN, OR BASIN No. 4.

The E. end of the large coal-field of Big Black Creek is penetrated from the E. by several parallel anticlinals, which subside W. within it.

ANTICLINALS P AND Q, AND BASINS *p*, *q*, AND *r*.

Two of these anticlinals, P and Q, are noticeable in that part of the basin which extends from near the Owl Hole westward to Fillmore. They subdivide the general basin into three subordinate but closely-connected troughs. The Southernmost of these, Basin *p*, appears to be narrow and short, not extending E. much beyond the Conyngham Road. The middle one, *q*, 1000 feet broad at the Fillmore Colliery, is the longest, heading E. within half a mile of the Owl Hole: this is Basin No. 3 of the Buck Mountain Company, who have newly opened a colliery in it by a shallow perpendicular shaft, sunk just in the synclinal axis at the point where a branch of Sandy Creek cuts off the upper strata, giving easier access to the coal.

The coal-bed at the new Buck Mountain Colliery, No. 3, consists of the following divisions: an upper bench, 9 feet in thickness, of merchantable coal, without slate; a middle bench, from 4 to 5 feet of good coal, rougher than the upper bench; a lower bench, 2 feet 6 inches of bony coal and slate.

The Northern basin *r*, shorter than the preceding, terminates E. very nearly opposite the Buck Mountain Company's shaft. It is much wider than the middle one, its N. outcrop being at the foot of the Southernmost high ridge of E. Buck Mountain. At Fillmore, and for some distance E. and W., the mean breadth of the basin is not more than half a mile.

Only one bed of coal has hitherto been proved in this division of the Black Creek Basin. It rests at a short interval above the main conglomerate, and is evidently the equivalent of the coal-bed of the two basins of the Buck Mountain Company's lands in East Pismire Hill. It is, in other words, the lowest productive coal of the series, and, for reasons already developed, cannot be the representative of the great Hazleton and Beaver Meadow Bed.

ANTICLINALS R, S, AND T, AND BASINS *s* AND *t*.

Three other anticlinals, N. of the preceding, enter the Coal-measures from the E., insulating two branches of the main Black Creek Basin between them, namely, *s* and *t*. Of the coal in these we know at present extremely little. Near the N. edge of the more Northern of these, or more than half a mile N.E. of Jeddo, or one-third of a mile E. of the ravine of Cross Creek, through the conglomerate ridge which bounds the basin, two shafts have been sunk in coal on the Jeddo Lands. The bed dips S. from 25° to 30°, and is in two branches, the upper one 6 feet thick, and the lower one 5 feet, with 3 feet of hard slate between them. Whether this is the lowermost, or Buck Mountain Coal-seam, or whether it is the Hazleton bed, is a question which must remain unsettled until the strata of this basin are more systematically exposed.

Big Black Creek Basin.—Between Jeddo and the Wilkesbarre Turnpike the Black Creek Basin appears to have an average breadth exceeding half a mile. Along its E. half it is somewhat wider than this, but from a mile E. of the road to the road itself, the area of the large coal gradually contracts, until the two outcrops unite at a short distance, it is believed, W. of the turnpike.

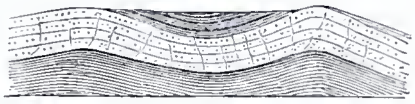


FIG. 215.—Black Creek Basin, E. of the Wilkesbarre Turnpike.

Extremely little is known of the contents of this basin. A large coal has been shafted just W. of the mouth of Cross Creek, on the N. side of Black Creek, dipping at the gentle angle of 10° N. Its thickness was not clearly ascertained. To which bed in the series this appertains, we cannot at present ascertain. The only other point in the basin where a large coal-seam has been opened is on the lands of Siverey and Longstreth, a point about one mile E. of the Wilkesbarre Turnpike ; this is on the N. side of the basin, the coal at its outcrop dipping 30° S. The bed here discovered is thick ; it is believed to be the equivalent of the great Hazleton bed, and from the distance of its outcrop from that of the upper beds of the great conglomerate, I infer that it can be no other. Near the W. end of this basin, and on the N. side of the synclinal axis, a deep and expensive boring has been made just W. of the Wilkesbarre Turnpike in quest of the large coal-seam. It is immediately N. of the N. outcrop of a thick pebbly sandstone or Pea-conglomerate, supposed by the engineer to be the cap-rock of the great coal-bed, but which is in reality the overlying stratum to one of the lowest small coals, probably the second in the series. The boring failed to reach any coal, but was not deep.

There is a small detached basin *n* in the general synclinal belt, No. 4, extending as far W. as Barne's Run. This embraces the lower Coal-measures ; it is pretty well ascertained to contain none of the large upper bed of Hazleton.

BASIN No. 5.—LITTLE BLACK CREEK BASIN.

Too little is known of the limits of the Coal-measures, and especially of the upper or Big bed in this basin, to authorise our saying much respecting it. It evidently forks into two branches, perhaps a couple of miles E. of the Wilkesbarre Road, by the intrusion of a bold axis, V., of conglomerate, which penetrates this synclinal belt from the E., between the two Northern spurs of the East Buck Mountain. This axis lifts the conglomerate both E. and W. of the road leading from the Buck Mountain Mines to Howey's Tavern, insulating from each other the two basins of the lower Coal-measures *v* and *w*, branches of the basin of Little Black Creek.

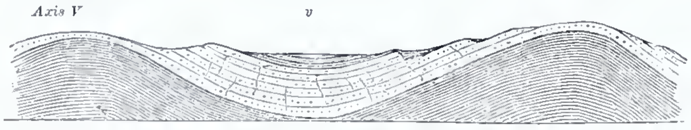


FIG. 216.—E. end of Little Black Creek Basin, Buck Mountain.

The large upper coal-bed has not been actually opened far to the E. of the Wilkesbarre Road, which is a long distance to the W. of where the basin forks. On the N. edge of the branch basin *v*, at a distance of a third of a mile E. from the road, a coal-bed, believed to be the lowest of the series, has indeed been proved. This point is designated on the Map as Roberts' Shaft. The outcrop is near to that of the conglomerate, and it shows a S. dip. At Balliot's Old Slope the Big Vein was wrought a few years ago upon its S. dip. The same large coal-bed has been opened about a fourth of a mile W. of the turnpike, upon its N. dip, and S. of the Little Black Creek. It there possesses the full dimensions of the great Hazleton bed, its total thickness being 27 feet.

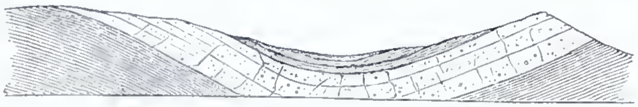


FIG. 217.—Buck Mountain, or Little Black Creek, E. of the Wilkesbarre Turnpike.

The W. limit of the large coal in this basin, according to those who have attempted to trace it by the external indication of its outcrops, is from 1 to 1½ miles W. of the Wilkesbarre Turnpike. At the turnpike the N. edge, or outcrop of the Big Coal, is S. of Little Black Creek.

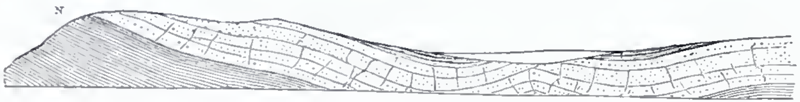


FIG. 218.—Little and Big and Black Creek Basins, near the junction of the two branches of Black Creek.

The lower Coal-measures extend in this basin to the neighbourhood of the Berwick Turnpike, beyond which they have been swept away by the general denudation of the surface.

BASIN OF MAIN BLACK CREEK, OR BASIN No. 5 WEST.

Along the whole line of the Main Black Creek, from the mouth of Cranberry Creek westward to Roberts' Creek, there extends a synclinal belt of the Coal-measures; but whether these embrace any of the large upper bed of the region, has not yet been ascertained. From the mouth of Cranberry Creek to within 3 miles of the sudden turn N. of Black Creek, or a distance of 5½ miles, this strip of the Coal-measures is narrow, and apparently quite shallow; but at that place the belt rapidly widens, becoming more than half a mile broad; and it is quite possible that this division of the basin may contain some of the Big Coal. Crossing Black Creek near its great bend, the coal-basin, pursuing its course W., but gradually contracting in breadth, ascends the valley of Roberts' Creek, a distance, it is believed, of about one mile. Coal has been opened near the turn of Black Creek, both E. and W. of the stream, on the S. side of the basin, dipping about 20° N. Coal has likewise been opened further W. up the valley of Roberts' Creek.

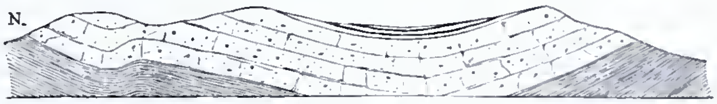


FIG. 219.—Buck Mountain west of Black Creek Gap.

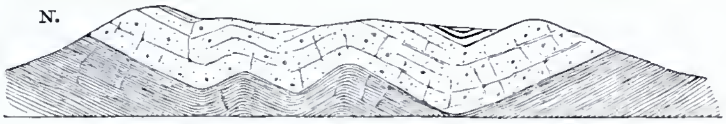


FIG. 220.—West End of Buck Mountain.

EAST GREEN MOUNTAIN BASINS, No. 6.

Basin No. 6, *x.*—Of the two basins already stated to exist in the general synclinal table-land of Green Mountain, the largest and most important is that of the W. half of the mountain. The E. extremity of this wide and regular coal-field is not more than one-fourth of a mile N.E. of Howey's Tavern. Its W. extremity is probably about half a mile E. of the W. terminating knob of the mountain; the whole basin, therefore, has a length of at least 2½ miles. Its central and widest portion is about half a mile broad. It seems to lie somewhat obliquely on the mountain, its S.E. margin approaching quite closely to the anticlinal belt of Red Shale at Howey's Tavern, and its Northern margin approximating quite closely to the N. edge of the table-land at the head of Hell-Kitchen Ravine, one of the few localities where any coal has been opened in it.

At this last-named spot a bed of coal, evidently a large one, has been mined to a small extent on Larkin's estate. Its outcrop is about 300 feet from that of the conglomerate. It dips very gently S., being indeed almost flat. The thickness of the coal here has not been fully proved, an upper bench being nearly washed away at the entrance of the drift. The only portion mined is a bench 7 feet thick, the upper bench crushing down upon this within the drift. Coal has likewise been opened and mined to a small extent by a gin near the S. edge of the basin, about 1 mile W. of Howey's. Here the prevailing dip is to the N. 25°. Both here and at the Hell-Kitchen Ravine the coal much resembles that of the great Hazleton bed, being of excellent quality.

The surface-features of this mountain-basin are remarkably smooth and regular, implying a relative absence of interior undulations or disturbances, and on the whole this promises to be a valuable coal-field.

Basin No. 6, *y.*—The other and smaller basin of East Green Mountain is situated about a mile N. of the White Haven Road leading E. from Howey's Tavern. This small trough of Coal-measures is seated on the N. verge of the table-land N. of the anticlinal undulation X, which divides it from the preceding coal-basin. It is believed by those who have examined it for coal, to be about three-fourths of a mile long, and about 1200 feet broad. Hitherto it has disclosed but one coal-bed, which at its outcrop, exposing coal and coal-dirt, measured in the trial-shaft about 8 feet in thickness. It dips gently S., the shaft being on the N. side of the basin, and about 150 yards from the outcrop of the conglomerate. It would appear to be the lowest, and perhaps the only one, in the basin.

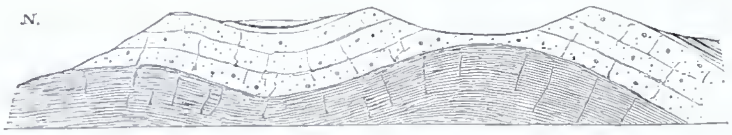


FIG. 221.—Section of East Green Mountain Basin.

BASIN No. 7, OR THAT OF McCAULEY MOUNTAIN.

There is a small patch of Coal-measures on the summit of McCauley Mountain, an insulated outlying synclinal hill, situated about 9 miles E. of Catawissa. The length of the strip of productive coal-strata in this elevated little trough is apparently about 2 miles, and its breadth from a fourth to a third of a mile. There are two large beds of coal here, the equivalents in all probability of some of the thick seams of the Lower White-Ash group of the Shamokin and Nanticoke coal-fields. This long-neglected little basin has been recently connected with the market by a short branch-railroad from the Catawissa Road.

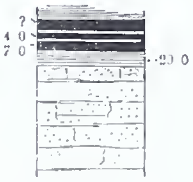


FIG. 222.—Coal-bed of McCauley's Mt.

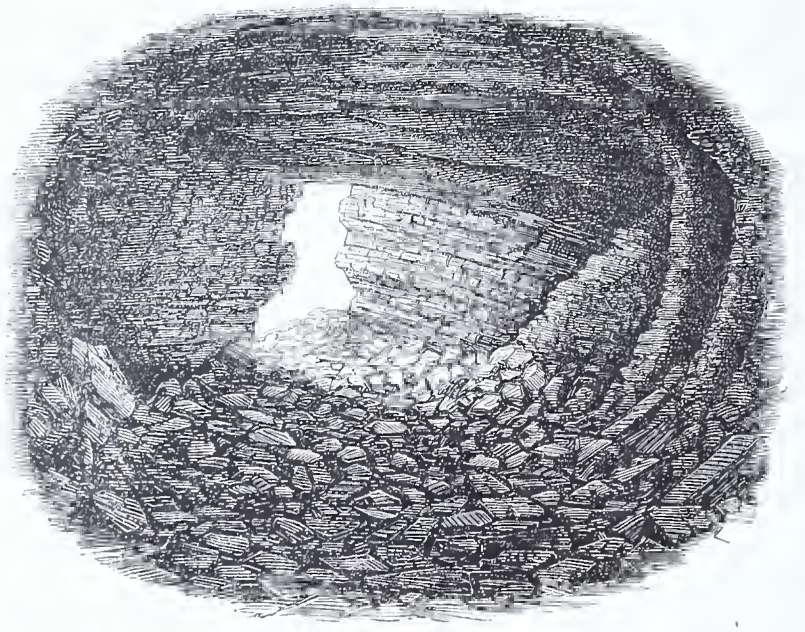


FIG. 223.—One of the Cave Workings in the South Mine of the Great Lehigh Summit Coal Seam: height about 40 feet.

DIVISION III.

WESTERN MIDDLE COAL-FIELD.

CHAPTER I.

MAHANOY COAL-REGION.

GENERAL STRUCTURE AND TOPOGRAPHY.

For the sake of clearness in the classification and definition of the several parts of the extensive and complicated Western Middle Coal Region, I propose to call this, in general terms, the Mahanoy-Shamokin Basin or Coal-field, as being one great synclinal district of coal-bearing rocks, almost entirely insulated, or surrounded by valleys of the Umbral red shale. It is essentially one great coal-field, there being no belt of any other rocks than the coal-conglomerate penetrating into or subdividing it. Being almost exclusively watered by the Mahanoy and Shamokin creeks, it is best designated by the united names of these two streams.

This whole coal-field is partially but not entirely separated into two compound or undulated basins of productive Coal-measures by the elevated anticlinal mountain-ridge called Locust Mountain, which, in the central and Western portions of its length, exposes along its crest a narrow belt of the Seral conglomerate, which there divides the true coal-bearing rocks of the Western half of the Mahanoy Valley from the same strata of the Eastern half of the Shamokin Basin.

The proper designation for all that part of the coal-field which is embraced between the head-waters of the Quakake and the Little Schuylkill on the E., and the W. source of Locust Run of Shamokin Creek on the W., is the Mahanoy Basin; for, except in its extreme Eastern spurs, and at its extreme Western end, it is everywhere drained by the tributaries of the Mahanoy. From its Eastern spurs to Big Mine it is bounded on the S. by the Mahanoy and Broad mountains, and on the N. by the Big or Head Mountain, and from Big Mine Run to Locust Knob, the Western termination of the basin, its Southern boundary is still the Mahanoy Mountain, whilst its Northern is now the crest of the Locust Mountain. It should be distinctly understood, however, that the Locust Mountain is not continuous with the Big Mountain, and therefore does not completely insulate this basin from the Southern branch of the proper Shamokin Basin, the two being really united by the subsidence E. of the Locust Mountain axis, at the head-waters of Big Mine Run.

The Shamokin Basin is bounded on the S. by the Locust Mountain crest from Big Mine Run to Locust Knob, and thence Westward to the extremity of the basin by what should properly be called the Locust Mountain, but is frequently entitled the Mahanoy Mountain. On the N. the basin is limited by the monoclinal crest of the Thick or Shamokin Mountain.

The W. end of this basin is watered by the sources of Zerbe's Run, which falls into the Mahanoy in the Red Shale Valley outside of the coal-field, and not into the Shamokin. At the head-waters of Big Mine Run, this basin, as already intimated, is actually connected with that of the Mahanoy, by the declension Eastward of the Locust Mountain anticlinal, which allows the Coal-measures an uninterrupted extension by a narrow belt from the one field into the other.

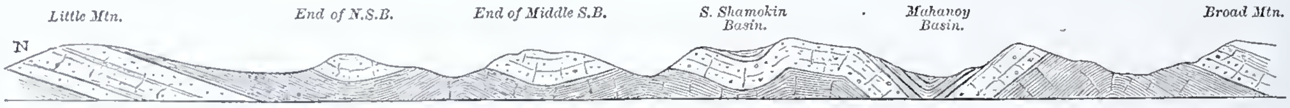


FIG. 224.—General Section from Little Mountain to Broad Mountain, across the Shamokin and Mahanoy Basins E. of Big Mine Run.

MAHANOY AND SHAMOKIN COAL-REGION.

In our general description of the structure of the anthracite region, the external boundaries of the Mahanoy and Shamokin coal-region have been already defined, and the great anticlinals of the country indicated, which elevate the belts of Umbral red shale outside of it, and impart to the whole coal-field its general trough-like configuration.

This extensive coal-region is not, however, a simple synclinal trough, but possesses a quite complicated structure from the presence within it of a number of anticlinal and synclinal undulations. Upon a correct knowledge of these mainly depend the successful development and economical mining of the coal contained within the strata ; and I therefore proceed to a systematic description of these flexures as the groundwork of my whole statement of the distribution of the several coal-beds.

In tracing the anticlinal and synclinal lines which define respectively the saddles and troughs of the district, I will observe the order already adopted for the Pottsville Basin, commencing, that is, with the most Southern axes, and describing each axis in its course from E. to W. While tracing the anticlinals or saddles, due mention will be made of the *lowest* coals which they elevate to the surface at successive points, and in specifying the synclinals or basins embraced between the saddles, similar allusion will be made to the highest coal-beds included within these troughs, or which have escaped denudation. The reader should consult the 3d Section on Plate IV.

DETAILED DESCRIPTION OF THE ANTICLINAL AND SYNCLINAL FLEXURES.

FIG. 225.—East End of Head Mountain, looking W.

Properly regarded, the Mahanoy and Shamokin coal-field commences at the E., in the high synclinal knob or spur called the Head Mountain, which juts forward into the Red Shale Valley of the Quakake. Expanding into a wide and elevated plateau, it ranges Westward, and about 4 miles from its E. extremity throws Northward a broad flat anticlinal platform, to connect itself with the E. crest of the Spring Mountain. Here the plateau across which the Hazleton and Tamaqua Turnpike passes to descend through Lindner's Gap, has a width of nearly a mile and a half. From Lindner's Gap the table-land, contracted to an average width of one mile, ranges on for about 3 miles to the head of the deep anticlinal cove of red shale which lies E. of the source of Little Pine Creek. Here the whole basin is suddenly enlarged by the addition of all that portion which embraces the three E. tributaries of the Mahanoy. This expansion of the general basin arises from the introduction, going Westward, of the whole synclinal trough embraced between the anticlinal of the Red Shale Cove, and the monoclinal crest of the proper Mahanoy Mountain. That section of the basin which extends from the Red Shale Cove here mentioned, to the region of the W. head of the cove of the Hassasock, includes therefore the prolongation of the table-land of the Head Mountain, here known as the Big or Shamokin Mountain, and also the E. end of the true synclinal valley of the Mahanoy. These two divisions are connected by a wide tract of nearly horizontal strata, extending from the head of the Red Shale Cove to the mouth of the North Mahanoy, a belt which may be regarded as produced by the dying-away of the anticlinal of the Red Shale Cove at the one end, and of that of the Bear Ridge at the other. It does not appear that the E. anticlinal actually arches the strata to any great distance Westward of the cove, for at the sources of Pine Creek, and the North Mahanoy, the rocks are nearly horizontal; nor does it appear that the Bear Ridge axis is prolonged Eastward as a true wave to any extent beyond the gap of the North Mahanoy, yet the effect of these two anticlinals, nearly coincident in line, is to lift and flatten the lower Coal-measures along the whole course of the North Mahanoy stream, and the central ridge which bounds it on the S.

Anticlinal of Head and Big Mountain, No. 1.—The Big Mountain, with its E. prolongation, the Head Mountain, carries an anticlinal undulation centrally throughout nearly its whole course E. from the Middleport and Catawissa Road, and it is to the presence of this line of uplift that the mountain owes its elevation and table-land form.

The topographical features and the dips of the strata alike indicate that the undulation passes out of the plateau Eastward through its S. margin, at a point about 2 miles E. of the Tamaqua and Hazleton Turnpike—a conspicuous knob in the side of the mountain, indicating the point of emergence where it enters the Red Shale Valley to the S. of the Head Mountain. From this point Westward the axis grows progressively sharper as far as the gorge of the East Branch of the creek down which the turnpike passes, and beyond this it seems gradually to flatten down again in its dips as it ranges on to the district opposite the North Mahanoy. In this latter neighbourhood it manifests itself in the high and regularly-arched form of the conspicuous mountain-knob which extends for about a mile to the S.E. of the deep cove or hollow in the N. side of Big Mountain. The same anticlinal is visible at the crossing of the Middleport and Catawissa Road, and may be traced indeed along the high broad summit of the Big Mountain for some miles still further Westward.

Coal Basins of Head and Big Mountain, Nos. 1 *and* 2.—The nearly central anticlinal of the Head and Big Mountain divides two small coal-basins which occupy a part of the summit of the plateau in the vicinity of Lindner's Gap. The whole synclinal table-land being here more sharply undulated by the steeper flexure of this anticlinal than further Westward, the two troughs which bound the saddle, one on the S., the other on the N., contain here a moderate thickness of the lower Coal-measures. But the flattening and lifting of the anticlinal in its course Westward appears to throw out these coal-rocks ere we reach the vicinity of the Red Shale Cove north of Pine Creek. What the exact limits E. and W. of the productive Coal-measures may be in either of these basins, it is impossible, in the present unopened condition of the district, to define. The more Southern basin, or that just N. of Lindner's Gap, is evidently the narrowest, but being bounded by steeper dips than the other, may possibly contain two or three of the lowest coal-seams. It does not seem probable, however, that this trough contains any Coal-measures whatever beyond a mile or so E. of the gap, nor is it likely that these rocks range Westward of the gap more than 1 or 2 miles.

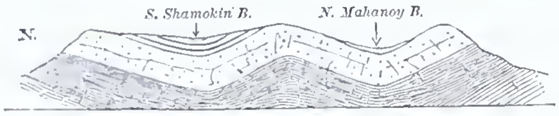


FIG. 226.—Head Mountain, S.W. Side of Lindner's Gap.
Note.—The Cut does not represent sufficiently steep dips in the S. Basin.

In regard to the extent of the Coal-measures in the N. trough, or that which terminates in the knob of the Head Mountain, our information is equally vague. It is probable that here the Coal-measures extend considerably further Eastward than in the narrower basin to the S. of it, but it must be observed that in this basin the dips are gentle, and the whole trough of the coal-bearing rocks is therefore necessarily very shallow.

An extensive denudation of the Coal-measures in the vicinity of Lindner's Gap has contributed to reduce their depth. The ready outlet afforded by the breach of the Southern Mountain, at this place, to the denuding currents which have swept over the region, has permitted them to excavate a large amount of the coal strata, which are everywhere softer than the conglomerates that support and confine them. The same denuding action appears to have succeeded in carrying off the entire mass of the Coal-measures from nearly every other part of the Big Mountain, where the flatness of the undulations has given the waters a grasp upon the upper strata ; for it is almost an invariable rule, that our high mountain table-lands contain but little coal, except in those troughs where a considerable steepness of dip or depth in the synclinal flexure has served to protect the upper or exposed coal-formation between the less destructible mountain-barriers of conglomerate. In confirmation of this statement of the general removal of denudation of the Coal-measures from the table-land of the Big Mountain, it is only necessary to state that we find nothing but the upper beds of the Seral conglomerate across the whole breadth of that plateau, either on the Tamaqua and Catawissa Road, the Middleport and Catawissa Road, the Newcastle and Catawissa Road, or, indeed, over any part of the mountain-summit between them.

BEAR RIDGE ANTICLINAL, AND THE SOUTH BASIN OF THE MAHANOY SOUTH OF IT.

Axis No. 2.—The axis of Bear Ridge first conspicuously displays itself in a fine arch E. of Westhouse Run, or about one mile W. of Faust's Tavern, and N. of the Mahanoy. It ranges thence with a steadily-increasing amount of flexure along the summit of the Bear Ridge, crossing the ravines of Westhouse Run, and the stream next W. of it. From this latter stream to the W. end of the ridge near Girardville, the anticlinal axis ranges along the N. slope of the ridge, a little below its sharp and rugged crests, throughout nearly all this part of its course. The flexure is very steep, or almost perpendicular, on the N. side of the axis, the main summit of the ridge being everywhere composed of moderately-inclined South-dipping conglomerates of the lowest Coal-measures, until we approach its W. extremity, where the S. dips likewise become very steep. The annexed cut, from a sketch taken about half a mile E. of the ridge, will serve to exhibit the

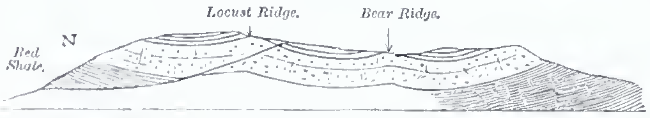


FIG. 227.—Mahanoy Basin at Eastern Origin of Bear Ridge Axis. (The Dips are shown too flat.)

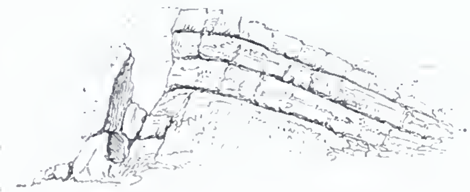


FIG. 228.—Broken Anticlinal Crest of Bear Ridge, half a mile E. of the Ridge.

abruptness of the anticlinal flexure, and the rugged character of the crest, resulting from so sharp a change of the dip.

Axis No. 3.—An important anticlinal belt traverses the entire length of the general Mahanoy and Shamokin coal-field, from the Red Shale Cove, which is near the head of Pine Creek, to the vicinity of Ashland. As already intimated, it does not actually arch the strata between the Red Shale Cove and the mouth of the North Mahanoy, but merely lifts and flattens the rocks which support the productive Coal-measures ; nor is it at all certain that the anticlinal axis of the cove is strictly in line with that which originates near the mouth of the North Mahanoy, and runs Westward at least as far as Westhouse Run, yet we may safely view the two, and the flat region between them, as constituting one anticlinal belt bounding the proper coal-basin of the Mahanoy on the N.

The rise of the anticlinal just W. of the mouth of the North Mahanoy causes the commencement of the basin of the Coal-measures north of that axis, and, at the foot of the Big Mountain, makes its productive coal strata extend Eastward in this second trough as far as Coal Run, a small tributary of the North Mahanoy. It is here that a bed of coal, 10 feet in thickness, has for some years been superficially mined on the lands of Mr C. Loeser, of Schuylkill County. But Eastward of Coal Run this basin seems to expire, any Coal-measures that it once contained having been washed out in the denudation which made the valley of the North Mahanoy. How far to the Westward this axis No. 2, and the coal-basin to the S. of it, may extend, we cannot now determine.

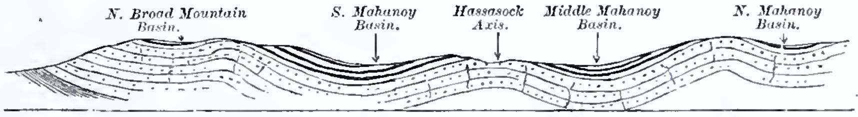


FIG. 229.—Section W. of Mouth of North Mahanoy, looking W.

In the vicinity of Faust's Tavern there occur on the flanks of the basin of the South Mahanoy at least three beds of coal, the lowest in the series. One of them is perhaps the equivalent of Loeser's large seam ; but we have no evidence of the presence so far Eastward in the basin of the great bed of the East Boston Basin, the equivalent apparently of the so-called Jugular Vein of the neighbourhood of Ashland. Nearly opposite the centre of the East Boston Basin, or about 2 miles W. of Faust's, and rather low on the N. slope of the Mahanoy, which is here called the Broad Mountain, two beds of coal have been opened by experimental shafting. The uppermost of these, or that nearest the base of the mountain, is stated to be 20 feet thick ; it is, therefore, probably the equivalent of the large New Boston bed, the distance between their outcrops not exceeding about 1 mile ; the other, or lower seam, is said to have shown in the shaft a thickness of from 7 to 9 feet. They are about 30 yards asunder on the outcrop.

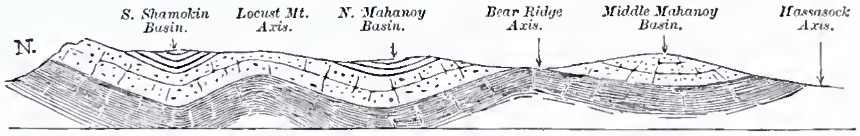


FIG. 230.—Section of East End of the Mahanoy Coal-field.
(The S. and middle N. dips are too gentle.)

COAL-MEASURES IN BEAR RIDGE.

It is obvious that the anticlinal of Bear Ridge elevates very low strata in the productive Coal-measures, if it does not, indeed, lift to the surface in the district of its maximum rise the subjacent Seral conglomerates. In the Girard Tunnel it would seem that the upper beds of coarse Seral conglomerate do rise to the level of the

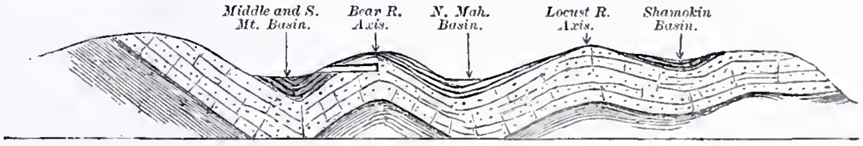


FIG. 231.—Section at the Bear Ridge Tunnel.

tunnel, and we find the same rocks on the crest of the ridge in several places between this point and its W. knob. The flanks of the ridge, however, support some of the lower coal-seams.

The anticlinal axis of the Bear Ridge does not cease with the termination of the ridge itself near Girardville, but may be traced Westward through the valley of the Mahanoy. We may, indeed, recognise indications of this axis at several points on the Old Pottsville and Danville Railroad, as at Girardville; and again, one mile W. of it, and even still further W., near Big Mine Run. W. of this last-named locality we may detect at one point a gentle N. dip of the Coal-measures, and yet further Westward, an extent of horizontal bedding which seems to imply the final dying-down of this extensive anticlinal. It is possible that these last phenomena do not belong to the Bear Ridge, but to some other more trivial one, yet they are so nearly in its line of prolongation Westward as to justify us in ascribing them to it. While it thus commences at the sources of the Mahanoy, in strata below any productive coal-seams, here, at its W. extremity, near Ashland, it affects some of the highest of the Coal-measures of the Mahanoy Basin, the bed of which it does not arch, but merely flattens.

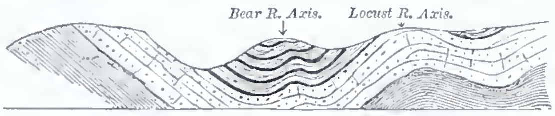
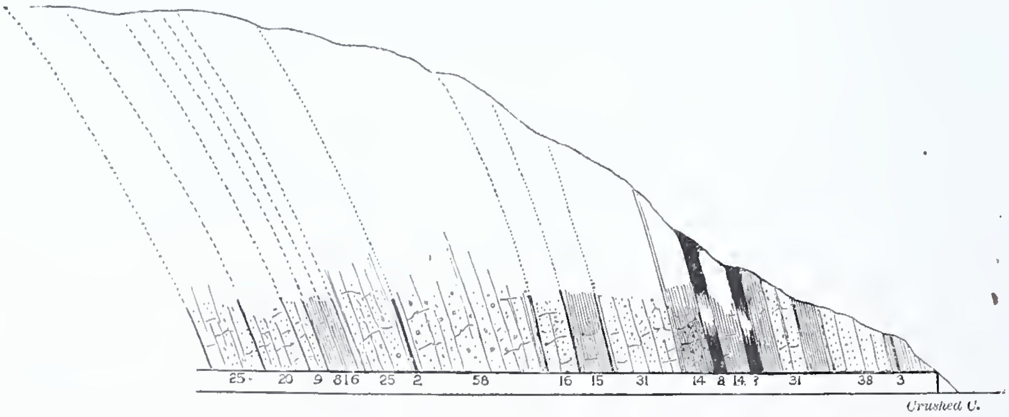


Fig. 232.—Western Origin of Bear Ridge Axis.

Basin No. 3—the Mahanoy Basin proper, or the South Mahanoy Basin.—The basin or synclinal valley of the Mahanoy, bounded on the N. by the anticlinal of Bear Ridge, which we have just been tracing, and on the S. by the monoclinal crest of the Eastern Mahanoy Mountain, by the N. brow of Broad Mountain, and Westward of this by the crest of the proper Mahanoy Mountain, commences at the E. in the sharp synclinal knob lying between Pine Creek and the Red Shale Cove north of it. The gorge of Pine Creek reveals distinctly its synclinal structure, but discloses no Coal-measures so far Eastward in the trough. Passing Westward down the symmetrical spoon-shaped valley of the South Mahanoy, we detect in the terraced features of both the Mahanoy Mountain and the middle ridge of the basin the topographical indications of the lower coal-beds. Opposite Faust's Tavern, on the Middleport and Catawissa Road, the productive Coal-measures rise on the N. slope of the Little Mahanoy Mountain to an elevation of nearly 300 feet above the South Branch of Mahanoy, and their upper margin ranges nearly level from this point Eastward along the flank of the mountain, preserving a line about half-way between the stream in the bed of the valley and the N. edge of the mountain summit. By the rise of the basin, this nearly level line gradually approaches the foot of the mountain, until it turns to constitute the extreme Eastern end of the basin of the coal-rocks. This will be found to be somewhere within or just E. of the Paul Hannah Tract of the Girard Lands, and but a short distance W. of the extreme head of the South Branch of the Mahanoy. The N. line

Fig. 233.—Bear Ridge Tunnel, Mahanoy Basin, looking E.—1 *inch* = 100 *feet*.



of the basin may be traced from this point nearly due Westward to the mouth of the North Mahanoy, and thence Westward a little S. along the summit of Bear Ridge.

Axis No. 4—Shenandoah Axis.—A third anticlinal axis is traceable through the interior of the Mahanoy Coal-field, commencing at the S. foot of the Big Mountain, E. of Coal Run, and terminating, so far as we are able to ascertain, a little W. of Big Mine Run, near Ashland. It is faintly visible N. of the North Mahanoy and on the Middleport and Catawissa Road. Ranging Westward, it passes along the crest of the ridge, the S. slope of which contains the source of Westhouse Run, and crossing the next stream, it follows the same ridge prolonged to where this is cut by the Shenandoah, south of Patrick Kaley's house, on the Newcastle and Catawissa Road. The anticlinal ridge, which, E. of this intersection, bounds the Shenandoah Creek on the S. after being cut by it, forms the N. boundary of the valley of that stream to its junction with the Mahanoy. The crest of this ridge, carrying the axis, passes about three-fourths of a mile N. of Girardville, and about the same distance N. of the mouth of Big Mine Run. In this neighbourhood it is the South-bounding ridge of the valley of the East Branch of Big Mine Run. This arch is not exhibited far to the Westward of the main Big Mine Run, its last appearance being recognised in a coal-shaft on a vein of slaty coal which just saddles the axis. It probably expires before reaching the Catawissa Road, its only effect there being a lifting of the table-land which lies S. of the main crest of Locust Mountain. Throughout its range, from the Middleport and Catawissa to the Ashland and Catawissa Road, it traverses a wild region entirely undeveloped, and it is impossible to specify the portion of the Coal-measures brought up to the surface along the crest of the wave; we only know that at its E. extremity it lies N. of the margin of any productive Coal-measures, and in the vicinity of Patrick Kaley's, on the Shenandoah, the Coal-measures saddle the axis, and on Big Mine Run it brings to view the strata which lie next below the great Mammoth coal-seam.

Basin No. 4.—We are equally at a loss to define the part of the coal series embraced within the basin which lies next S. of the anticlinal No. 3, which we have just been tracing; we can merely say, that at its E. extremity, near Coal Run, it contains Loeser's Ten-feet Coal low in the White-Ash measures; and that near its W. end, where Big Mine Run intersects it, it includes the Jugular and probably the Mammoth seams. In the intermediate tract, especially that of the valley of the Shenandoah, this basin is almost certainly deeper than towards either extremity; and if the axis No. 2 expires, as we have reason to think it does, before reaching the Shenandoah, this basin, here bounded on the S. by the Bear Ridge anticlinal, must be greatly deeper, and supplied with a far thicker series of Coal-measures. The determination of the W. limit of the feeble intermediate axis No. 2 will, therefore, be a point of much importance in any future explorations and estimates of the extent of coal in this part of the Mahanoy coal-field, now in chief part the property of the city of Philadelphia. Although the anticlinal axis No. 3 bounding this basin ranges nearly in a line with the great anticlinal of the crest of Locust Mountain, it would seem not to be continuous with it, but at Big Mine Run and further E. to lie nearly one-third of a mile to the S. of it. It is thus that axis No. 3 lifts and flattens the South-dipping strata of the S. flank of Locust Mountain, on the Ashland and Catawissa Road. (See Section, Plate IV.)

On Big Mine Run the belt S. of the anticlinal No. 3 contains two or three subordinate anticlinal undulations, at least two of which are recognisable near the Catawissa Road in the vicinity of Repplier's Tunnel.

Anticlinal Axis No. 5, or that of Ashland.—The next anticlinal is one of much importance in the structure of the Mahanoy Coal-field. It appears to originate somewhere between the Shenandoah and Big Mine Run, and to terminate Westward not far to the W. of the Old Minersville Road, towards the head of the general basin bounded by the Mahanoy and Locust Mountains. From Big Mine Run to the Minersville and Shamokin Road, this line of anticlinal flexure follows very nearly the crest of the middle ridge of the valley of the Mahanoy and Locust Mountains, or that which passes just N. of Ashland. This ridge possesses considerable breadth and elevation the whole way from Big Mine Run to Big Run, beyond the W. branch of which it rapidly declines. Throughout the chief part of its course the flexure is sharply folded with more or less inversion of the N. side of the wave; and there is good reason to suppose, as an inspection of our Section along Little Mine Run will show, that in some places the abruptness of the folding has resulted in an actual dislocation or fault. The folded form of the axis is clearly proved by the sections on Little Mine Run and on Locust Run at the Catawissa Road, and is finely exposed to view in an arch of the strata at the intersection of the ridge by Big Run further Westward. It assumes the character of a depressed normal arch when it reaches the Old Minersville Road. How it terminates to the Eastward we are not at present able to say.

If we view the subordinate undulations which, from Big Mine Run to Big Run, everywhere follow the N. side of this inverted flexure, we may regard the whole belt, between the folded axis and the synclinal axis at the foot of Locust Mountain, as pertaining to the inverted side of a completely-undulated and greatly-compressed wave. Viewed in this light, the structure of the Mahanoy and Locust Mountain basin, as exhibited in our several sections, will be more readily understood. Let us now pass to a description of this complex basin, and to the explanation of the sections through which we design to illustrate what is at present ascertainable respecting the Coal-measures which it includes, and the undulations which disturb them.

BASINS BETWEEN THE MAHANOY AND LOCUST MOUNTAINS.

Basin No. 5, or Ashland Basin south of Anticlinal No. 5.—This interesting and very valuable division of the Mahanoy coal-field is in part a prolongation of that trough, in the strata which we have styled the Mahanoy Basin proper, but which, ceasing with the cessation of the Bear Ridge anticlinal, expands itself into this.

From Big Mine Run westward, even to the junction of the Mahanoy and Shamokin mountains, or more strictly, to the Western end of the Ashland folded anticlinal, this Ashland basin has the structure of an almost perfectly regular trough. Its rocks rise from a central synclinal line or axis, where they seem to be nearly horizontal towards either side of the valley, with an almost symmetrical inclination; those on the S. side ascending into the N. flank of the Mahanoy Mountain, and those on the N. side into the S. slope and crest of the Ashland or Middle Ridge. The only departure from a strictly symmetrical structure is in the greater general steepness of the dip along the Southern, compared with that along the Western side of the basin, for the average inclination of the coal-beds and other strata in the Mahanoy Mountain is about 60°, while the opposite or S. dips, on the flank and at the foot of the Middle Ridge, does not much exceed 40°. This steepness in the N. dip in the Mahanoy Mountain prevails to the Western end of the whole coal-field, while the Southern inclination in the Middle Ridge gradually subsides to horizontality, as the axis of this ridge dies away Westward.

Two watersheds, or summits of drainage, occur in the length of this Ashland basin; they are not connected apparently with any upheavals of the strata, but are merely the results of denudation. The more Eastern one lies about midway between the Mahanoy and Big Run gaps, while the other is nearly midway between the Big Run and Locust gaps, the latter watershed being not far from the Western end of the Middle Ridge. The bed of the valley here is nearly level with the summit of that anticlinal range, and the entire surface of the basin, therefore, from mountain to mountain, is much elevated. Connected with these features there will probably be found a somewhat increased thickness or depth of Coal-measures in both instances; in the case of the watershed near Ashland, by a piling-up of the strata in the middle of the basin, and in that of the summit between Big Creek and Locust gaps by a similar addition of undenuded coals, assisted by the subsidence of the anticlinal flexure which elsewhere lifts all but the lowest measures from out of the centre of the coal-field.

Basin No. 6, or that of the S. Side of Locust Mountain.—Viewing this somewhat undulated synclinal belt as commencing somewhere in the vicinity of Big Mine Run, and as coalescing Westward at the point of subsidence of the folded anticlinal S. of it with the Ashland Basin, we may observe, from an inspection of the sections along Big Mine, Little Mine, Locust and Big runs, that towards its Eastern end is an elevated and much-disturbed tract of the lower Coal-measures; and this condition of things continues until we pass some distance Westward of Locust Run, the undulations occupying nearly the whole breadth of the belt between the folded anticlinal of the Middle Ridge and the normal axis of Locust Mountain; but as we approach the head-waters of Big Run, the plications and undulations no longer extend as far Northward across the basin, but become confined to its S. side, showing that they are not in reality undulations on the S. leg of the Locust Mountain arch, but are secondary disturbances connected with the great fold of the Middle Ridge. Contributing to this change in the structure of this disturbed belt, is a progressive cessation Westward of the more Northern of the smaller anticlinals which lie within it. First, the Shenandoah axis, or that next adjacent to the anticlinal crest of the Locust Mountain, expires a little W. of the Big Mine Run. In the next place, a smaller axis, made apparent in some shaftings near Big Mine Run, ceases at Locust Run, being detected there in Repplier's Tunnel, under features which show it to be fast expiring. A third subordinate saddle, visible on Big Mine Run just N. of the mine in the lower Big Coal bed, is, from evidence derived from shafting near the Catawissa Road, seen to be there subsiding, nor does it appear to pass far to the Westward of the ravine of Locust Run.

Not one of these three undulations S. of the Locust Mountain axis reaches the centre turnpike, where only a S. dip occurs from the summit to the base of the mountain. It is to the presence Eastward of these anticlinal waves or uplifts that we must impute the general rising in that direction along this belt of the lower Coal-measures, and the general elevation of the surface S. of the true flank of the Locust Mountain; and we must ascribe their absence Westward to the deepening of the valley between the mountain and the central ridge. Connected with this deepening there is doubtless a general deepening of the synclinal trough, or, in other words, an accumulation of Coal-measures admitting a greater number of coal-seams: this condition prevails to the Westward, until the general rising of the bottom of the whole double synclinal trough, indicated in the drawing together of the Locust and Mahanoy mountains, counteracts it, and finally shoals out the Coal-measures.

Along the S. side of the synclinal belt which we are considering, there ranges, connected with the inversion of the N. side of the folded anticlinal of the Middle Ridge, a compressed or folded basin, traceable from Little Mine Run to Big Run, and perhaps ultimately still further in both directions. While the South-dipping rocks of the N. side of this narrow trough decline at an angle seldom exceeding 45°, the same beds, where they are overturned to form its S. side, lean past the perpendicular, at angles as low as 55°, and in some instances lower than 50°. This extreme degree of inversion is visible in two or three of the drifts on the E. side of Big Run. On Big Run this folded synclinal exhibits less regularity than belongs to it on the Little Mine Run east of Ashland. An inspection of our sections will show that at Big Run the S. side of the basin, or, what is the same thing, the N. flank of the inverted anticlinal, is excessively disturbed and thrown into a succession of folds, in at least two of which there is visible an overlap of the strata upon themselves.

COAL-BEDS IN THE COAL-FIELD BETWEEN THE MAHANOY AND LOCUST MOUNTAINS.

(Consult Section on Catawissa Road and Ashland Gap.)

Mahanoy Gap.—The water-gap of the Mahanoy, in the mountain S. of Ashland, affords an excellent opportunity for measuring the thicknesses of all the strata, from the upper members of the Umbral series to the middle Coal-measures, and for determining the order of superposition of many of the coal-seams, and their several thicknesses. The mountain being here cleft to its base, and furnishing a great slant length, or, in miners' language, a high breast on the lower coal-beds, this spot is destined to become the scene of active mining operations; and as a preliminary to these, the coals have been systematically opened by a series of experimental shafts, and by several drifts penetrating the end of the mountain, forming the W. side of the notch, at an elevation a little above the stream.

Defining the several strata, as usual, in ascending order, the first mass we shall specially note is the Seral conglomerate.

Seral Conglomerate.—Understanding by this term the coarse unproductive portion of the Coal-measures, which, under the form of a thick succession of massive beds of nut and egg-sized conglomerates and pebbly sandstones, forms the floor of the lowest productive or even notable seams of anthracite, we may define it as here including but a comparatively small amount of sandstone, and as consisting mainly of beds of silicious pebbles of the full average coarseness. The thickness of this mass is about 600 feet, measuring it from the uppermost layer of Red Shale to the bottom of the first bed of coal.

Alternating with the upper portion of the Umbral series, occur five or six massive strata of grey silicious conglomerate and pebbly sandstones, in nearly equal thickness with the beds of Red Shale which separate them. These passage-beds, which mark the first invasion of the currents transporting the pebbly and sandy materials of the Seral Coal-measures, occupy, with the interposed layers of Red Shale—the last depositions of the tranquil waters thus invaded—a thickness of not less than another 600 feet.

First or Lowest Coal, No. I. of the Ashland Series.—The lowest coal is no more than 18 or 20 inches in thickness, nor does the seam contain this much of pure coal.

To it succeeds a massive bed of conglomerate, and another of sandstone, having an aggregate thickness of not less than 300 feet.

Coal No. II.—Upon this rests the second coal, impure and slaty, appearing to be 5 feet thick at its outcrop.

Between Coal No. II. and the next occurs a body of coarse grey sandstones, in thickness about 100 feet.

Coal No. III.—This third coal of the gap has been supposed to be the so-called Jugular Vein, of enormous thickness in the Mine Hill Basin. Here, at the water-level of the gap, it is believed to have a diameter of only 5 feet. Higher towards the summit of the mountain, and Westward along its N. crest, a coal, under the normal size of the Jugular, occurs, measuring as much as 28 feet, including in this thickness not more than 2 or 3 feet of slate, and 2 or 3 feet of impure or bony coal; but it is a different coal from No. III., being in reality, as our Section on Plate IV. shows, Coal VI. or the so-called Mammoth bed.

Above this 5-feet vein lies a Nut and Pea-conglomerate exceeding 150 feet in thickness.

Coal No. IV.—A small seam about 3 feet thick succeeds the Pea-conglomerate.

Sandstone and arenaceous slates, in thickness about 50 feet, now intervene between Coal No. IV. and the next coal-bed.

Coal No. V.—The fifth seam is likewise a very thin one, being only a foot or two thick.

A thickness of about 30 feet separates the Little Coal No. V. from the Great Mammoth Seam.

Coal No. VI.—This great bed, called the Mammoth Vein, in the Ashland Basin, measures at this place about 25 feet. It consists of three main benches of coal, insulated from each other by two dividing-slates.

About 120 feet of rock, chiefly coarse sandstone and Pea-conglomerate, divide the Mammoth bed from the next overlying coal.

Coal No. VII.—This is called the Six-feet Coal bed, but it usually contains not more than 4½ feet of coal. It includes two benches.

Succeeding the Coal No. VII. is a mass of Pea-conglomerate and sandstone about 160 feet in thickness, in which, at a depth below the next coal-bed of some 40 feet, occurs a stratum of shale, imbedding balls of iron ore.

Coal No. VIII.—Next in order is a coal ordinarily called the Twelve-feet Vein, but it is not in reality more than about 9 feet thick. This includes four benches.

Separating this coal from the next is a mass of sandstone, with a little slate, of a thickness of 70 feet.

Coal No. IX.—This is a double coal of two thin seams, the whole measuring, with the interposed slate, about 6 feet, and yet not containing coal enough to be workable.

About 30 feet of rock-sandstone now interpose, then we have the next coal.

Coal No. X.—Upon the sandstone rests a bed of coal, which, as it was shafted, seemed to have a thickness of 4 or 5 feet. This, at the Little Breaker, is shown in the Section.

A thick mass of Pea-conglomerate and coarse sandstone follows Coal No. X.: it has a thickness of not less than 160 feet.

Coal No. XI.—The next seam of coal is not a pure one, but consists of alternating coal and slate. In the shafts sunk upon its outcrop it appeared to have a thickness of 8 feet.

Succeeding this occur a grey sandstone and sandy slate through a thickness of nearly 200 feet.

Coal No. XII.—We now come to a thin coal-bed met within the point of the ridge just S. of the town of Ashland; the drift is obscure, and no record remains of the thickness of the seam, which is evidently not great.

Between this last-mentioned coal and the cessation of all rock-exposures near the middle of the valley, and nearly coincident with the main street of the village, there are about 200 feet of strata imperfectly visible, consisting of sandstones, slates, and shales, and in these have been found two or three very thin seams of soft and impure coal. This brings us to the uppermost Coal-measures, saved from denudation in this portion of the Ashland Basin.

We have here enumerated twelve independent beds of coal of various dimensions, from 2 feet to 25 feet; but of this series there are only about four which, under present circumstances, it is worth the while of the colliers in this district to mine upon a scale of any magnitude. So greatly more remunerative are the lower thick beds, extending in breasts more than half the height of the mountain above the water-level, that the thinner seams, especially the upper ones, are naturally for the present neglected.

FLEXURES AND COALS ON BIG MINE RUN.

The flexures and relations of the few coal-seams developed along Big Mine Run must be now briefly mentioned. There are three anticlinal undulations S. of the main axis of Locust Mountain. The most Northern of these is the Shenandoah anticlinal, or axis No. 4; and the most Southern is that which, a little E. of the Catawissa Road, lifts a large coal as it rises and expands to the E.; while the middle axis, apparently a very short one, is that which occurs in Repplier's Tunnel on Locust Run.

The large bed of coal shown dipping S. at an angle of 32°, as it is mined at Bast and Company's Colliery on the W. side of Big Mine Run, is, upon the most natural view we can adopt, the same seam which is seen dipping N. on the N. side of the Locust Mountain axis. From the position of this great coal, so far to the N. of the range of the most Northern ascertained outcrop of the Mammoth Vein, and from the uplifted condition of the strata, I am disposed to consider it as the Mammoth Seam of another flexure; and this view will receive confirmation upon a comparison of this section with those illustrating the state of things on Little Mine and Locust runs.

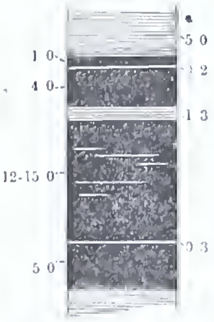


FIG. 234. — Mammoth Coal, Big Mine Run.

For the subdivisions of this so-called Mammoth Coal on Big Mine Run, see the cut here attached.

FLEXURES AND COALS ON LITTLE MINE RUN.

A study of the relative distances, thicknesses, and dips of the several coal-beds opened on the W. side of Little Mine Run, with the more conspicuous intervening rocks, makes it appear that there exist at that ravine two important anticlinal flexures, the more Southern one having the inverted form, while the more Northern has a normal shape. S. of the Southern or folded arch is one of the two very thick coal-seams of the district, the thickness of which at its outcrop is 26 feet, and next S. of this occurs another bed of medium size, here having a diameter of about 11 feet. This latter has been regarded by some persons as the true Mammoth bed, while the first-mentioned is considered by them to be the Jugular. Upon this view, the inverted coal seen next N. of the fold, and represented as 9 feet thick, is the lower or Jugular Vein, while that which outcrops next N. of this, and given in the section as 7 feet thick, must be regarded as the inverted leg of the arch of the Mammoth bed.

Opposed to this hypothesis is the fact that the fourth of these large coals, or the second one N. of the arch, is manifestly not inverted, but displays a top slate, with ferns resting in natural position *upon*, and not beneath it, and a bottom shale with Stigmaria *supporting*, and not overlying it. In its coal, moreover, it exhibits none of the ordinary signs of a movement of inversion, but exhibits every symptom of having been lifted only into a normal dip. It is, in other words, one of the most regular beds embraced in the section. We are therefore constrained, while we admit the inversion in the strata immediately N. of the arch, to assume a synclinal flexure just S. of this 7-feet bed; or to conceive, in other words, that the 9-feet inverted coal and it are one and the same stratum folded back again. Upon this view, which is inconsistent with the idea that these only moderately thick beds N. of the axis are parts of either the Mammoth or the Jugular coals, we can hardly avoid identifying them with the second bed S. of the arch, represented as containing a mine-drift, and as measuring 11 feet in thickness.

The coal, 11 or 12 feet thick, S. of the folded flexure on Little Mine Run, and called Patterson's, is shown in the accompanying cut.

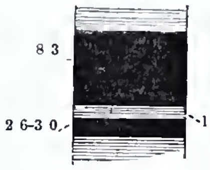


Fig. 235.—Patterson's Coal, Little Mine Run.

FLEXURES AND COALS ON LOCUST RUN, AND ON THE CATAWISSA ROAD.

(See Section, Plate IV.)

A recent revision of this neighbourhood (1857) has enabled us to clear up some of its seeming obscurity. The very persevering and skilful experimental shaftings and provings carried on adjacent to Locust Run, and on the Catawissa Road and in the Mahanoy Mountain at the Ashland Gap, have furnished us with data for the construction of a section which represents, we think, pretty nearly the true structure of this part of the coal-field. The great seam, or Jugular bed of Ashland, is thrown by a fault into two outcrops on the brow of the mountain. On the N. side of the basin it is folded back under itself into an inverted or S. dip, and its arch is denuded into two outcrops supposed till lately to indicate two separate large coal-beds. It rises again further N., twice to the level of the road, high on the slope and summit of Locust Mountain. The Section exhibits all the dips, distances, and thicknesses now ascertained by mining and measurement.

ANTICLINAL FLEXURES AND INTERVENING BASINS OF THE SHAMOKIN COAL-FIELD, WITH THE COALS WHICH THEY PRESENT.

Anticlinal No. 6—that of Locust Mountain.—This important axis, already defined as bounding the Shamokin Coal-field on the S., originates in the valley of the East Branch of Big Mine Run somewhere N. of Girardville, and apparently about one-third of a mile S. of the Southern slope of Big Mountain. It does not impress itself on the topography until it reaches Big Mine

Run, on the W. of which the arch indicates itself in a knob, around the E. end of which flows the W. branch of that stream. Rapidly ascending from this point Westward, it forms the S. part of the high table-land S. of the Shamokin Mountain, across which passes the Ashland and Catawissa Road. From the Catawissa Road westward it continues to rise nearly to the centre turnpike, beyond which it slowly subsides to the neighbourhood of Locust Gap, where the axis seems again to ascend in its progress, until, by finally lifting out the soft Umbral rock subjacent to the coal strata, it separates the conglomerate which previously spans it into two monoclinal outcrops, the S. one slowly swinging Southward to unite with the crest of the Mahanoy Mountain, and form the high synclinal summit called the Locust Knob, and the N. one holding onward, but deflecting slightly Northward, to constitute thence the monoclinal South-bounding mountain-ridge of the Shamokin Basin. Between the Catawissa Road and the Locust Gap, the line of this axis is not straight, but curves sensibly convex Northward; but from Locust Gap to the cove of Red Shale through which it passes out from between the Coal-measures, it appears to hold a nearly direct course.

Strata elevated to the Surface by this Anticlinal.—The rocks which denudation has laid bare on the back of this anticlinal wave at its Eastern origin, are the middle Coal-measures; but from Big Mine Run to a point about one-third or half a mile W. of its intersection with the Catawissa Road, they are only the lowest of the productive coal-rocks; while from the point mentioned to Locust Gap, and indeed throughout its entire length to the Red Shale cove at Locust Knob, the materials exposed are the different members of the conglomerate beds which underlie the true Coal-measures.

In that section of its length which extends from near the Catawissa Road to Locust Gap, especially the portion a couple of miles E. and as many W. of the centre turnpike, there would seem to be two or three subordinate flexures on the back of the main anticlinal wave, the more Eastern of these passing Northward of those originating further W., a structure which perhaps is connected with the slightly convex sweep of the mountain in this neighbourhood. The Map will illustrate their position.

In the deep notch, called Locust Gap, by which this anticlinal ridge is cut to its base, the upper Egg-conglomerate, in a massive stratum 40 or 50 feet thick, may be seen rising from the bed of the notch in a regular arch, the crown of which is about 100 feet above the level of the stream called Locust Run, which, issuing from the Western part of the Mahanoy Valley, flows N. by the gorge to join the Shamokin Creek. The arch here is nearly symmetrical, the strata of its N. and S. abutments dipping about 20°. On both sides of this arch are several regular terraces or benches, formed by the denudation of the softer strata—namely, the coal-beds, and the slates adjoining them; and these terraces or benches, as they are familiarly called, extend with greater or less regularity along both flanks of the mountain throughout its entire length.

Anticlinal No. 7—that of Mine Ridge and of Mount Carmel.—Passing, in the next place, to the consideration of the first long anticlinal N. of the foregoing one of Locust Mountain, and deferring the description of the several subordinate ones included between these two principal waves, until the synclinal belt including them is under treatment, we have an axis of remarkable length and straightness. Coming from the East, it follows for several miles the N. foot of the Big Mountain, to where this throws a spur Eastward about 2¼ miles N. of Girardville. Here the saddle enters the coal strata by leaving the Red Shale at the head of the cove, between the main mountain and its spur, and traversing a table-land of the Seral conglomerate between this cove and the Catawissa Road. This table-land, partly anticlinal, partly synclinal, contracts Westward beyond the Catawissa Road into a mere mountain-spur, along the S. brow of which now runs the anticlinal-line. One mile W. of the road, the broad spur becomes a narrow ridge of symmetrical profile, the crest of which droops quite rapidly thence to the forks of Shamokin Creek. This end of the mountain is called Mine Ridge. The anticlinal by no means terminates with the end of the ridge, but pursues its course in an exceedingly straight line for many miles Westward. Passing through the S. edge of the little table-land on which is seated the village of Mount Carmel, it ceases a mile further to elevate any ridge at all, but about 2 miles to the Westward of Mount Carmel it again makes an impression on the surface, holding up the low table-land over which the Mount Carmel and Shamokin Road passes, and which here begins to assume the name of Green Ridge. The axis follows the summit of Green Ridge to the gap through which the Shamokin Creek passes North-westward, exhibiting there a fine arching of the coal strata; and holding the same straight course, it extends along one of the crests of this ridge prolonged, till it crosses Buck (?) Run about 1500 feet S. of its mouth, at the bend of Shamokin Creek, beyond which, in the same line, it crosses Gerhart's Run, 700 feet above its mouth, and Mowray's Run, some 2900 feet S. of its junction with Carbon Run, following in all this part of its course the crest of the same narrow ridge. The Western termination of this anticlinal is in the high ground N. of the crest of Mahanoy Mountain, opposite the sources of Carbon Run. By the slow Northward trend of the Mahanoy Mountain, this anticlinal, like several others which adjoin it, gradually converges towards that ridge, rising and flattening itself as it obliquely approaches the crest or N. flank of the mountain. Opposite the vicinity of Locust Gap, this Mount Carmel anticlinal presents its greatest depression, and is the only section of its course where it is at all obscure: but for the perfect coincidence in line between its Eastern and Western halves, we might suspect that there are in reality two flexures—one sinking Westward to this neighbourhood, and the other Eastward from the flank of the Mahanoy Mountain. Future mining operations will probably determine the question of the strict continuity of the two portions of this long anticlinal line. The fact that the Locust Mountain axis undergoes a considerable subsidence of level in this vicinity, seems to be confirmatory of the view here presented of the strict continuity of the Mount Carmel flexure.

Strata exposed by Denudation along this Anticlinal.—From the head of the cove of Red Shale, not far E. of the Catawissa Road, to a point about 1½ miles W. of that road, the different members of the Seral conglomerate present themselves in succession, arching over the anticlinal axis as it very slowly sinks towards the W. At the point where the last uppermost beds of the unproductive conglomerate hide themselves, and the Coal-measures in ascending order saddle the axis, the anticlinal crest commences to fall more rapidly, descending in the next mile and a half to the point of Mine Ridge. The most Eastern spot at which clear indications of coal have been discerned by us, is upon, or very near, the crown of the arch, and about 1½ miles E. of this termination of the ridge. This coal appears to be one of the lowest; but all that part of the coal series which spans the anticlinal near the end of the ridge has been explored for coal, and three beds have been brought to light. The lowest principal bed here denuded at the very axis into two outcrops is probably Coal No. VIII. of the Shamokin Basin series. It has a thickness at these outcrops of 13 and 16 feet. A higher coal is exposed at Mount Carmel, just S. of this axis; but from Mount Carmel westward for more than 3 miles, we know at present extremely little of the coal-beds which arch the anticlinal in the most depressed part of its course. Where Green Ridge, however, begins to assume some elevation S. of Quaker Run, the strata have been successfully explored for coal; and about 1½ miles E. of Green Ridge Gap, the large coal, No. 8 of the series, has been cut from off the summit of the wave into two outcrops. At the arch in Green Ridge Gap (see fig. 236), the generally thick Coal No. V. ascends above the water-level to span the axis, forming a curve about 1100 feet wide at its base. Buck Ridge, as that part of the hill between Green Ridge Gap of Shamokin and Buck Run is called, likewise exposes a narrow belt of the lower Coal-measures, between two outcrops of Coal No. VIII. Westward of Buck Run, the anticlinal slowly rising and the denudation growing upon it proportionately less, the two outcrops of Coal No. VIII. approach each other, until they coalesce again a little E. of Gerhart's Run. From this ravine to our Cross Section, Westward of Shamokin Gap, the axis is saddled throughout by very nearly the same division of the Coal-measures—that is to say, Coal No. VIII., which in some places overlaps it, and in others is denuded into two contiguous outcrops.

To assist to a full understanding of the strata exposed along this extensive line of flexure, the reader will do well to consult our sections across the coal-field, commencing with that next W. of Ashland, and terminating with the section W. of Shamokin Gap.

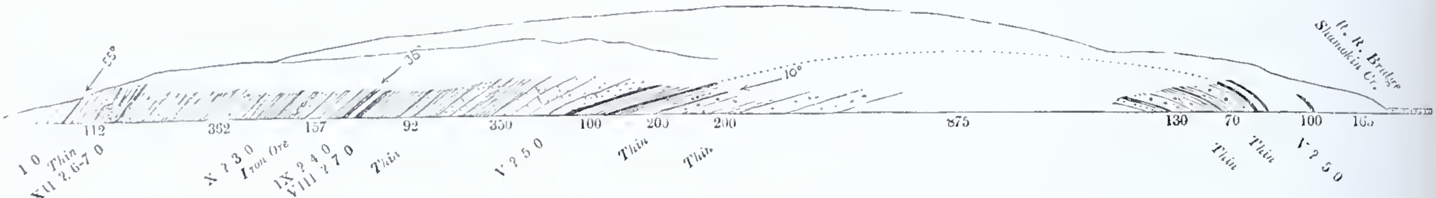


FIG. 236.—Section at Green Ridge Gap.

SYNCLINAL VALLEY OR BASIN NO. 7, BEING THAT BETWEEN THE LOCUST MOUNTAIN AND MOUNT CARMEL ANTICLINALS, AND HERE CALLED THE MOUNT CARMEL BASIN.

As already intimated, this long valley in the strata is connected Eastward with the Northern trough of the general Mahanoy Basin, by the subsidence in that direction of the anticlinal of Locust Mountain. That trough, situated on the S. base of Big Mountain, and limited Southward by the Shenandoah anticlinal, or No. 4, has its E. origin at the N. branch of the Mahanoy; its greatest breadth N. of the Shenandoah stream and ridge; and its junction Westward with this Mount Carmel Basin in the vicinity of Big Mine Run. There it forks, by the rising-up of the axis of Locust Mountain, into two subordinate troughs. The Northern one, following the base of the Big Mountain, which presently becomes the Shamokin Mountain as we pass the watershed between the Mahanoy and the Shamokin streams, soon takes the form of a wide symmetrical trough between the wide axis of the Locust Mountain and that of Mount Carmel. From the Catawissa Road, where the Shamokin and Big Mine Run of Mahanoy nearly interlock, the bed of the valley gradually descends Westward, watered by the Southernmost branch of the Shamokin as far as the gap in Jamie's Ridge, one-third of a mile E. of Mount Carmel. The S. branch of Shamokin Creek, joined by the middle branch at the point of Mine Ridge, and flowing forward half a mile within the basin, breaks through the low double ridge of Mount Carmel, Northward; it flows along the N. base of the Northern or Jamie's Ridge, breaches it by a second gap half a mile Westward of Mount Carmel, and, crossing the two anticlinals, enters once more the Basin No. 7, which we are describing. A little further Westward, the N. branch of Shamokin, after passing through a third notch in Jamie's Ridge, and thus crossing both that axis and the true Mount Carmel one S. of it, likewise falls into the Shamokin Creek in this well-watered basin. From this point the main Shamokin stream maintains its course within the basin for several miles, until, being opposed by the rise of a group of small Western anticlinals, it is deflected Northward so as to pass out of the trough through the picturesque gap of Green Ridge. But in this middle part of the basin several mountain tributaries, the chief one of which is Locust Run, entering it through Locust Gap, contribute to swell the Shamokin Creek, and to irrigate the surface of the valley.

The configuration of this basin is that of a simple synclinal trough the whole way from the Catawissa Road to Mount Carmel; but, passing the latter locality, its structure becomes more complex through the introduction of first one, and, further Westward, of several subordinate anticlinal flexures, the influence of which is seen in the increasing variety and seeming irregularity in the topographical features of the district, as we trace it Westward to Buck Run. Viewed largely, the basin presents from this cause three divisions, as respects its structure and its scenery: an Eastern one, a simple mountain-trough watered by the S. branch of the Shamokin; a middle one, drained by the main Shamokin, and not bounded on the N. by any well-defined ridge or creek, but by a low and irregular table-land; and a third Western one, a high-rolling plateau leaning against the Mahanoy or monoclinal prolongation of Locust Mountain, and rising gradually Westward to merge itself into it as part of its long Northern slope.

SUBORDINATE ANTICLINAL FLEXURES IN THE MOUNT CARMEL BASIN.

Before proceeding to a statement of the Coal-measures actually developed and inferred to exist in the different parts of the Mount Carmel Basin, it is expedient to take a rapid glance at the subordinate flexures which undulate its bed.

Anticlinal A *of Basin* 7.—Commencing with the most Eastern subordinate axis, and referring to the Map to convey an exact conception of its position, I may describe it as originating on the E. at the foot of Mount Carmel somewhere near our section, for no vestige of this flexure is to be seen on the centre turnpike. Passing about 1000 feet S. of the mouth of the North Branch of the Shamokin, its structure is best exposed in this neighbourhood, where it crosses the Shamokin Road, and afterwards the Shamokin Creek, about 1200 feet N. of Locust Run. Entering the wide low table-land of Green Ridge, it disappears as a mere low wave in the strata. Everywhere throughout its course this is a very flat or gentle flexure, and its influence, therefore, in lifting out the Coal-measures, is comparatively unimportant. It is the principal cause, however, of the broad high plain which spreads N. from the foot of Locust Mountain nearly to the Shamokin Creek, and over which passes the Minersville Road.

The lowest coal-bed lifted to the surface anywhere along the course of this anticlinal, seems to be that which the Coal Mountain Company is now mining near the axis, and which I am disposed to regard as Coal No. 9 of the Shamokin Series. This seam is about 6 feet thick, and comprises three or four benches of coarse hard bird's-eye coal; this is at the Old Orchard drift.

Anticlinal B *of Basin* 7.—Next in order among the subordinate anticlinals of the basin is one which seems to originate some distance W. of the Western termination of the preceding, and a little S. of its line of bearing. It commences, that is to say, N. of the Shamokin Creek, on the S. side of the table-land of Green Ridge, and crossing the Shamokin near the concave bend above the mouth of Wackle's Run, it passes through the N. side of the point of Buck Ridge, the main crest of which it then follows as far as Buck Run. Here the flexure, marked by a steep S. dip and a very gentle N. one, is still discernible; but how far beyond this stream it prolongs itself, we are unable, in the obscure condition of the surface, and the absence of mine-openings, to determine. It would seem, however, not to reach our section E of Gerhart's Run. This anticlinal, in the middle part of its range, or from the end of Buck Ridge to Buck Run, appears to be a flexure of considerable steepness, especially as respects its S. side,—a fact which is distinctly expressed in the topography of the belt of country traversed by it. Its N. dips are very gentle in consequence of the contiguity of a flat anticlinal to the N. of it.

Of the coal-beds elevated to the surface along this anticlinal we know but little, except near the E. end of Buck Ridge and at Buck Run. Nowhere does it seem to expose to view the large coal, No. VIII., but throughout its length it is saddled by the group included between that coal and No. XII. or XIII. Coal XII. has been opened by shafting just at the axis on the N. slope of the point of Buck Ridge, and one or two beds between that seam and Coal VIII. are accessible at the passage of the axis across Buck Run.

Anticlinal C *of Basin* 7.—There is a small flexure developed by shafting very near the Mahanoy Mountain, on the cross section at the sources of Gerhart's Run. In position it seems to lie somewhat to the S. of the course of axis B of Basin 7. This short flexure originates apparently somewhere near the Shamokin and Mahanoy Road, and, running W. obliquely towards the crest of the mountain, dies away high on its flank opposite Mowray's Run. The coals which it arches are those immediately above the large seam, No. VIII.

Anticlinal D *of Basin* 7.—Just W. of the passage of Shamokin Creek, across the end of Buck Ridge, and through Green Ridge, we detect another anticlinal flexure on the N. flank of Buck Ridge. Whether this axis exists at all in Green Ridge, or to the E. of the Shamokin Creek, is at present a matter of doubt, but the topography of that table-land does not intimate its presence. It is a flexure of considerable length, and of remarkable parallelism with the axis of Buck Ridge, and indeed with all the subordinate flexures of the Western division of Basin 7. It is not more than 600 feet distant from the main Buck Ridge anticlinal, or axis B, both at the end of the ridge, and on Buck Run; and on the section at Gerhart's Run, it is distant from axis C about 1000 feet. In its Eastern portion it is a wave upon the N. flank of Buck Ridge; in its Western, an undulation on the long slope of the Mahanoy Mountain.

There is a very feeble flexure of the strata from 700 to 1000 feet N. of the crest of the mountain, or from 400 to 700 feet S. of axis E, indicated on the local cross-section of the Scott and Hunter tracts, and this is probably the W. prolongation of the anticlinal D.

Coals exposed along Axis D *of Basin* 7.—Near the end of Buck Ridge, Coal No. XII., or the same seam which saddles the anticlinal B in that neighbourhood, arches over this flexure, and separates, going Westward, into two outcrops. In like manner, as we advance along the anticlinal, after once attaining the summit-level between the Shamokin and Buck Run, and especially as we descend into the ravine of Buck Run, lower and lower coals are exposed by the W. ascent of the axis, and by denudation, until near the bed of that ravine the large coal, No. VIII., is accessible on both its dips above the water-level. Passing Buck Run, the next higher coals lap over the anticlinal, and even when we reach the section at the head of Gerhart's Run, only the covering rocks of Coal VIII. are at the surface, the coal itself not cropping out. Here the S. dip of the saddle being extremely gentle, we have an intimation that the axis is almost exhausted, and that, after forming for a short distance a belt of horizontal measures, it vanishes altogether, and leaves its space occupied by only N. dips. In the central part of its range, or where it crosses Buck Run, the N. limb of this arch becomes extremely steep.

Anticlinal E *of Basin* 7.—The fifth and last-recognised anticlinal of the Mount Carmel Basin is, like the preceding, confined to its Western division, or that beyond the Green Ridge Gap. Originating on the N. slope of Buck Ridge east of Buck Run, it crosses this stream above its forks, and, ranging parallel with the others, runs on to the tributaries of Buck Run, which it likewise crosses as it rises obliquely past the head of Mowray's Run into the sloping flank of the Mahanoy Mountain, where it disappears. Both on Buck Run and Gerhart's Run the N. side of this flexure is very steep; but at the more W. of these localities its S. dips, also steep at Buck Run, have become very gentle. This marks a near approach to the final termination of the flexure, the manner of its disappearance being evidently analogous to that of anticlinal D next S. of it.

Coals exposed on Axis E *of Basin* 7.—At Buck Run the anticlinal E exposes both dips of Coal No. X. immediately at the axis, a little above the water-level of the ravine; but E. and W. of the stream, where the denudation has been less, the next higher coals seem to lap over the arch; even on the cross section at Gerhart's Run, a coal, apparently the same, has been shafted just at the axis on a N. dip; and it is not until we reach a point opposite Mowray's Run that it appears to bring up Coal VIII. Still further W., for the anticlinal is a long one, it exposes at the cross section of the Scott Tract, and probably at a cross section a little W. of this, the still lower coal, No. VII.; here the flexure is within 1200 feet of the crest of the mountain, and its S. dips are very feeble, showing that it is almost gone.

Anticlinal F *of Basin* 7.—We come now to the last of the W. group of anticlinals included within the basin bounded by the main axis No. 7. It is seemingly a short and feeble undulation of the strata, not recognisable as far E. as Gerhart's Run, and not developed on Mowray's Run, if indeed it exists there. Our knowledge of it is confined to the developments made by shafting on the local section of the Scott and Hunter tracts.

Coals on Axis F, *Basin* 7.—The lowest coal exposed to view near this axis is Coal V., showing that this is a flexure of considerable lifting power, or, in other words, that it is here rising rapidly to the Westward.

OF THE SEVERAL SUBORDINATE BASINS EMBRACED IN BASIN NO. 7, OR THAT OF MOUNT CARMEL, AND OF THE COALS CONTAINED IN THEM.

Proceeding now to the consideration of the subdivisions of the Mount Carmel Basin, or those lesser synclinal flexures into which it is separated by the anticlinals just above described, and to the Coal-measures which have been preserved from denudation in them, and commencing as usual at the E. end, we have to note their positions and contents as follows:—

Basin a of Basin 7.—Designating the E. division of the general basin No. 7, or that watered by the South Branch of the Shamokin, as basin *a*, we will here recall attention to what has been already said respecting the simplicity of its synclinal structure. Bounded on the S. by the axis of Locust Mountain, which exposes throughout nearly the entire length of this trough the conglomerates below the coal-seams, the S. border of the Coal-measures within this trough is usually from 500 to 800 feet below the crest of that mountain. The only exception to this state of things is W. and E. of the Catawissa Road, where the lower Coal-measures themselves saddle Southward over the axis, to pass uninterruptedly into the N. basin of the Mahanoy. From the vicinity of the Catawissa Road westward along the flank of Locust Mountain the limit of productive coal gradually gets lower on the mountain as far as the centre turnpike, beyond which it as slowly climbs its slope again towards the Locust Gap. On the opposite side of the basin, the true coal-bearing rocks ascend to within a few hundred feet of the crest of the Mine Ridge Spur of the Big or the Shamokin Mountain, as we may here indifferently designate the high plateau traversed by the Catawissa Road. The gradual sinking of this anticlinal Westward causes the boundary of the coal to approach the crest, and finally to cross it at a point once before indicated as that of the disappearance of the conglomerate on the back of this broad saddle. This point is rather more than 1½ miles W. of the Catawissa Road. From thence to the point of the ridge at the fork of the South Branch of Shamokin, higher and higher Coal-measures come in along the N. edge of the basin, until the large vein No. VIII. there shows itself; and with the progressive subsidence of the axis, a considerably higher coal occupies a like position at the turnpike at Mount Carmel. It is obvious, then, that whereas only the lowest part of the White-Ash coal series has been retained within the trough in the vicinity of the Catawissa Road, a much more elevated portion of the Coal-measures remains in the W. end of this division of the coal-field in the neighbourhood of Mount Carmel. There, indeed, the upper coals pertain apparently to the Grey-Ash group, or the bottom of the Red-Ash group; and supposing the entire series of the Shamokin coal series in existence thus far towards the E., at a point not positively established, there must lie within the centre of the trough in this neighbourhood not less than thirteen or fourteen separate coal-beds.

Basin b of Basin 7.—The introduction of the low subordinate anticlinals or saddles *a* and *b* to the S.W. of Mount Carmel, divides the general basin No. 7 into two lesser troughs. The more S., and much the most capacious of these, situated along the foot of the Locust Mountain, and prolonged into the flank of the Mahanoy Ridge, we designate as basin *b* of Basin 7, while that N. of the two saddles, ranging for the chief part of its length through the plateau of Green Ridge, we may entitle basin *c*.

The branch basin *b*, traversed in the middle part of its course by the Shamokin Creek, and there bounded on the N. by Green Ridge, commences more than one mile E. of Locust Gap, and ends apparently W. of Buck Run, probably at the head of Gerhart's Run.

Coals in Basin b of Basin 7.—Throughout nearly its entire length, from opposite the North Branch of Shamokin to the head of Buck Run, this fine trough of the Coal-measures contains all, or nearly all, the coal-seams embraced between the bottom of the series and the Grey-Ash group. Even E. of Locust Run, it probably holds relatively narrow tracts of the Tenth, and even the Twelfth beds; and in its more central districts, probably the Grey-Ash coals themselves, or about No. XIV. This last statement is rendered probable by our finding Coal XII. saddling the axis of Buck Ridge near the E. end of that hill. Even as far Westward as the head of Buck Run, we find what is probably Coal XI. near the centre of this basin, and No. X. itself has been shafted in the same central line of the trough on the section just E. of Gerhart's Run. The statements already made respecting the coals brought to view along the two saddles *a* and *b*, will suffice to indicate the lowest which have their outcrop along its N. margin. It is along its S. border, or in the terraces of the Locust and the Mahanoy ridges, that the lowest coal-beds basining within this trough have their outcrops at the surface. There they may be mined by slopes, and in some of the more favourable ravines by drifts, endwise into the mountain, but along the central or synclinal portion of the valley they will be best reached by perpendicular pits or mine-shafts.

On both sides of Locust Gap, Coal VIII., or the Mammoth Seam, is now mined. On the E. side it presents the dimensions and divisions shown in the cut.

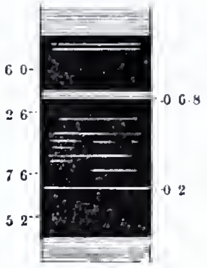


Fig. 237.—Connor's Mammoth Coal, Locust Run.

Basin c of Basin 7.—The Northern of the two branch basins of Basin 7 commencing near Mount Carmel, and bounded by the saddles *a* and *b*, receives for the first 2 miles the drainage of Shamokin Creek, till this stream is deflected by the E. end of Green Ridge into basin *b* South of it. From this point of passage of the Shamokin to its place of return Northward through Green Ridge, the basin lies entirely in the broad flat low table-land forming the E. end of the ridge—this table-land being the result, in fact, of the anticlinals of Buck Ridge, and of Green Ridge or saddle *b*, and the main axis No. 7. To the W. of the Green Ridge Gap the trough soon terminates as a simple synclinal, by the introduction of the anticlinal flexures *d* and *e* ; and indeed it is not expedient to regard it as a simple basin W. of the passage of the Shamokin through the ridges.

Coal-beds preserved in Basin c.—Coal X. appears to be the highest bed yet developed or likely to be found in that part of basin *c* which is occupied by the Shamokin Creek, though Eastward of the commencement of the trough, or near Mount Carmel, higher beds, as I have already shown, lie in the same belt of ground. The insertion of the saddle A evidently renders this basin more shallow than the wider one E. of it. The W. division of the trough, or that occupying the table-land of Green Ridge, possesses probably about the same portion of the coal series until we approach the Green Ridge Gap, where Coal VIII., lifted by the Westward rise of the main anticlinal No. 7, occupies the Northern half of this trough. It is probable that coals as high as the twelfth of the series find a place in the basin along the S. side of Green Ridge, for there both the anticlinals A and B are either much depressed or altogether absent.

OF THE NARROW TROUGHS IN BASIN No. 7, W. OF GREEN RIDGE GAP.

It will be seen, upon inspecting the Map and Sections, that between the main axis No. 7 and the more local anticlinal B, the three subordinate saddles D, E, and F form, with these others, four parallel narrow synclinals in the prolongation of basin *c*, which we have been just describing. Having already indicated explicitly the several coals denuded at the axes of these anticlinals, it is unnecessary to mention in detail what highest coals are preserved within these four respective troughs. It will be sufficient to call attention to the sections which cross them, and to the general fact that the coal-beds IX., X., and even XI. and XII. in the higher grounds, are procurable in the less denuded portions of these basins between the Green Ridge Gap and Gerhart's Run ; while W. of this stream, Coal VIII., and even yet lower coals, are generally the highest retained beds.

SHAMOKIN BASIN.

At the date of our last visit to the mines of the Shamokin Basin (September 1854), the following Coal Companies were in operation in the vicinity of Mount Carmel and Shamokin :—

Coal-Run Improvement and Railroad Company.—A tunnel was driven Northward across the measures into the South-dipping rocks of Red Ridge from a point N.E. of Mount Carmel; at 34 feet from the mouth, it cut a coal measuring from 6 to 9 feet, of good quality. This bed has not much surface above it, and the tunnel was continued to a distance of 122 feet, where a thin seam of 1 foot was cut. Beyond this, larger coals are to be met, which the tunnel had not reached.

Locust Mountain Coal and Iron Company.—This Company at the same date were driving a tunnel Northward into Red Ridge, farther Eastward and 50 feet higher than the Coal-Run Company's. The first coal met in this tunnel was struck at a distance of 233 feet; it measured 2 or 3 feet. A slaty seam 1 foot thick was met 51 feet farther in, and at the end of the tunnel, 318 feet from the mouth and 34 feet from the slaty coal, a seam corresponding to the 9-feet bed cut near the mouth of the Coal-Run Company's Tunnel was passed through. It was proposed to push forward 120 yards more where the large seam, Coal VIII., would be met. Before reaching it, two smaller coals would be passed: the upper bed measures 4 or 5 feet at the outcrop; the lower 9 feet, though it is generally much thicker. The large bed will have a breast of 240 feet, at a dip of 50° or 60°.

On the line of our Section south of the above collieries, and on the N. side of Little Mine Ridge, a fine bed of coal overlying Coal VIII. is mined by Mr Eckel on a steep N. dip. Its thickness and subdivisions are annexed:—

	Feet.	Inches.
Coal,	3 to 4	0
Slate,	0	6
Coal,	6	0
Slate,	0	6
Coal,	4	5

The gangways are driven Eastward. The coal below, or No. VIII. of the Shamokin series, is mined in the same neighbourhood. Its subdivisions are as follows:—

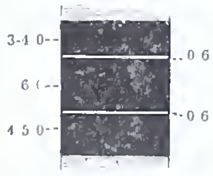


FIG. 238.—Eckel's Coal VIII., near Mount Carmel.

	Feet.	Inches.
Coal, good,	1	6
Coal,	3	0
Coal, bony,	0	6
Coal,	4	3
Slate and bony coal,	1	6
Coal, rough,	2	6

This coal has been opened on gentle S. dips on the S. side of Little Mine Ridge, and both of the beds have been proved yet further Southward on the N. dips of Locust Mountain, where their dimensions are large.

The *Coal Mountain Coal Company* are working two mine-drifts in the gap of Jamie's Ridge, W. of Mount Carmel. The Southern gangway enters a South-dipping bed of coal. Its thickness between top and bottom slates is 10½ feet, including 7 feet of workable coal. Not over 50 yards N. of this a 6-feet bed of coal is entered. The dip is 60°. The two openings are probably on the same seam. E. of Jamie's Ridge Gap the "Old Orchard Drift" enters upon a 6-feet bed of coal, dipping 5° N. The coal is divided into three or four benches, and exhibits a hard coarse bird's-eye variety.

The *Green Ridge Coal Company* have coal opened on both flanks of two anticlinals—that of Jamie's Ridge on the S., and Red Ridge on the N.

No. 1 drift-mine enters upon a coal dipping 45° S. on Jamie's Ridge; the coal measures 9 feet in four benches; the top bench, 4 or 5 feet thick, is the best. No. 2 mine, on the N. dips of the same axis, enters a coal 10 or 11 feet thick. The dip is 56°. This coal, and that of No. 1 drift, are no doubt the same. Over it several smaller coals are found. The lowermost measures 2 feet, a second 4 feet, and a third is not fairly proved. No. 3 gangway belongs to a bed dipping 15° or 20° S. from Red Ridge anticlinal. This seam is estimated to contain 16 or 17 feet of coal in five or six benches, of which the upper two and the lower are the best. Its ash is a light grey. The coal in No. 4 mine dips from 45° to 50° N. It is 13 feet thick, divided into several benches by partings of slate. From this mine 11 feet of coal are workable. The arch of Red Ridge anticlinal is finely exposed between Nos. 3 and 4 drifts.

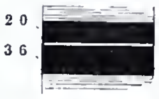


Fig. 239.—No. 1 Mine, Lancaster Colliery.

In Locust Gap, S. of the Green Ridge Company's mines, several fine seams of coal have been proved, and extensive collieries are about going into operation.

The *Lancaster Colliery* is situated near the end of Coal Run Ridge. Annexed are Sections of the coal-seams of Mines No. 1 and No. 2 of this colliery.

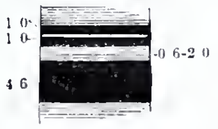


Fig. 240.—No. 2 Mine, Lancaster Colliery.

Anticlinal No. 8, *or that of Red Ridge.*—The next high leading anticlinal of the coal-field N. of No. 7, or that of Mount Carmel, is that of Red Ridge. This is actually traceable continuously no further than a little W. of the North Branch of Shamokin Creek, but as an axis exists almost precisely in the same line, about 2 miles further W., near Hornberger's, and the topographical features of the intervening ground are indicative of such a flexure, we can hardly hesitate to consider them as the same, and thus to extend the axis nearly to the valley of Shamokin Creek. But there occurs another anticlinal almost strictly in the same prolongation, ranging through the hill N. of the Shamokin Creek, and crossing the valley of that stream about 2000 feet N. of the mouth of Buck Run; and though I would by no means maintain, in the present imperfectly opened condition of the country, that this is a still further extension of the same axis, I deem it highly probable that it is a part of it. Possibly these two sections of the anticlinal W. of the North Branch of Shamokin may not be in exact line with each other and with the axis of Red Ridge, yet they lie so nearly in one range, and belong so strictly to the same belt of strata, that we cannot go far wrong for either scientific or practical deductions, if we view them as one continuous flexure. Adopting this enlarged notion of the anticlinal, it is one of the most important in the Shamokin coal-field, for it enters it at its Eastern end, issuing from the Northern of the two coves of Umbral Red Shale, or that embraced between the two Eastern spurs of the Shamokin Mountain; and ranging across the table-land of the Catawissa Road, and along the narrow crest of Red Ridge to its termination, it does not cease until it reaches the valley of Carbon Run.

This anticlinal flexure is of the normal type, like the other main ones which accompany it—that is to say, neither side of the curve is inverted. That portion of it which constitutes Red Ridge exhibits, like the anticlinal of Locust Mountain, a generally steeper S. than N. dip, neither inclination in Red Ridge exceeding, except in a few places, 45°. At the W. point of Red Ridge, and again near Little Quaker Run, and still further W., where it crosses the Shamokin S. of the furnace, the N. slope of the wave is in each instance a little steeper than the S. An additional fact connected with this anticlinal is the progressive steepening of the flexure as it prolongs itself Westward; for while, in its Eastern half, its dips, as stated, seldom surpass 45°, those which it exhibits where it crosses the Shamokin Valley south of the town of Shamokin, are as steep as 60° on the S. side, and 70° on the N. side of the axis. This pinching-up of the wave, as it were, is by no means an uncommon feature in our anticlinals. In the present instance it appears to be connected with the unusual multiplication of flexures in that part of the basin which lies opposite Shamokin, a multiplication which suggests an unusual amount of inward compression of the two boundaries of the basin, produced probably at the elevation of the great external anticlinal waves, between which the whole coal-field lies as one corrugated or wrinkled trough. The true Western termination of this axis I have not been able to ascertain, but it is probably somewhere near the sources of Carbon Run.

COAL-MEASURES EXPOSED BY DENUDATION ALONG ANTICLINAL No. 8, OR THAT OF RED RIDGE.

At the passage of the Ashland and Catawissa Road across the Red Ridge anticlinal, the only rocks exposed for a distance of many hundred feet are the middle and upper beds of the Seral conglomerate, and we encounter on the axis the upper beds of the Umbral Red Shale; but a short distance—perhaps not a third of a mile—to the E. of this road, the anticlinal, which is here by no means steeply arched, by slowly subsiding Westward, allows the two margins of the lower Coal-measures, which it separates, to encroach gradually upon it as it sinks, until at a distance of about a mile W. of the Catawissa Road these outcrops unite, and thence forward to the termination of Red Ridge, and indeed to the Western cessation of the axis itself, it is saddled only by productive Coal-measures. At first the crest of Red Ridge is overlapped only by the lowest of the workable coal-seams, but near its point, where the North Branch of the Shamokin cuts through it, the large coal-seam No. 8, which may be viewed as in the middle of the White-Ash series, presents its two outcrops closely approaching each other, and within 1000 feet or so W. of the gap: these outcrops run together, and this, and even higher beds, from that point forward bend over the axis without being cut or denuded. Between the mouth of Cedar Run and Little Quaker Run, or the mouth of Big Quaker Run itself, much obscurity prevails respecting the coals brought to the surface along the anticlinal; we only know that they must be high in the series. That part of the axis which crosses Shamokin Creek exposes, near the water-level of the stream, coals which our Section shows must be about the thirteenth or fourteenth of the series, or those next above the White-Ash group, and it is obvious that somewhat higher beds prevail along the ridge through which the axis passes. The present state of the district does not enable us to be more specific.

Basin No. 8, *or that included between Anticlinals No.* 7 *and No.* 8.—The long narrow trough or basin embraced between the Mine Ridge or Mount Carmel anticlinal axis, and the similar axis of Red Ridge and its prolongation on the N., though quite as long as the basin S. of it, is both narrower and of less complexity. It contains, as far as we know, only four subordinate anticlinals, one of them in its Eastern half, and three in its Western. Before proceeding to the distribution of the coal in the basin, it is essential to describe these anticlinals and their effects on the strata.

Anticlinal A *of Basin* 8, *or Axis of Jamie's Ridge.*—This anticlinal seems to rise near the point of Mine Ridge, and to diverge Northward from the Mount Carmel axis at a very acute angle, and follow the crest of Jamie's Ridge. It holds up the N. edge of the plateau of the village of Mount Carmel, as the Mount Carmel axis does the Southern. Crossed by the South Branch or

Main Shamokin Creek once E. and again W. of Mount Carmel, it is next, at the distance of half a mile, at the third notch in the ridge, traversed by the North Branch of the Shamokin. From this point Jamie's Ridge grows wider and flatter, and indicates through its external structure less precisely the position of the anticlinal; but further to the W., where the axis crosses Quaker Run, we are once more enabled to fix its place with precision: this is just S. of the passage across the stream of the Shamokin Road. From this point it ranges on in the same straight course towards Quaker Run, beyond which we lose it.

The want of parallelism of this axis to the two principal ones which adjoin it, is a feature deserving of especial attention, particularly when we note that a similar want of parallelism prevails between axis A of Basin 7, and the main anticlinal No. 7, and that these two oblique anticlinals are themselves mutually parallel. This fact would seem to suggest that they owe their birth to a different movement from that which produced the larger anticlinals between which they are enclosed, and that they can hardly be regarded as merely secondary corrugations of the strata engendered by inward lateral compression of the sides of the general basin, or the special ones including them.

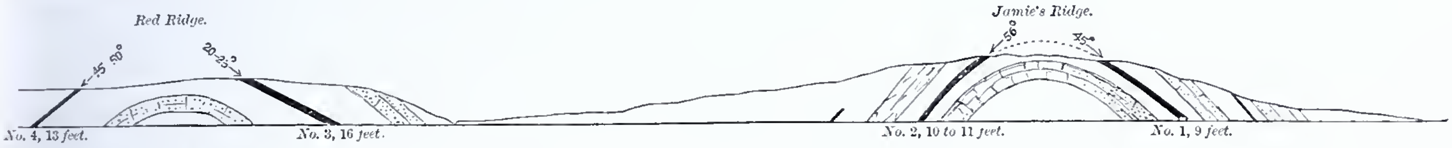


FIG. 241.—Section of Green Ridge and Red Ridge at North Branch of Shamokin Creek at the Collieries, looking E.

OF THE COAL-MEASURES EXPOSED ALONG AXIS A OF BASIN 8, OR THAT OF JAMIE'S OR GREEN RIDGE.

At the intersection of this anticlinal by the North Branch of Shamokin Creek—the point, namely, where the amount of vertical uplift along it seems to have been greatest—the lowest coal lifted into view above the water-level of the valley is the large seam, No. VIII. This spans the arch in a beautiful curve, dipping S. at an angle of 35° and N. at one of 50°; the bed is here about 12 or 13 feet thick. Outside of it, at each base of the ridge, are other higher coals. From this gap of the North Shamokin east half a mile to the passage of the main Shamokin, through the same ridge, the two outcrops of the large seam, ranging along the opposite sides of the ridge, gradually converge, until they come together just E. of the Shamokin. The E. descent of the anticlinal axis implied in this convergence, causes the coal to be saddled by higher strata from this gap E., so that at Mount Carmel the only coals exposed at the surface are those next above the big one. Still further E., again, the influence of the Mount Carmel axis upon this one shows itself in slightly lifting all the strata in that direction, so that Coal VIII. once more emerges from below the water-level.

In the opposite direction, or W. from the North Branch of the Shamokin, the axis either maintains its level for 2 or 3 miles, or sinks very slowly. Just S. of the axis on Quaker Run, a large coal has been opened in two places, that nearest the saddle measuring about 10 feet in thickness. Whether this is Coal VIII., or a bed higher in the series, we have not the data for determining; but I am disposed to regard it as a higher coal, probably No. X. or No. XII. Still further to the W., just on the S. brow of the low flat hill S. of Hornberger's, a coal has likewise been found basining a little N. of this axis, but what its thickness is, and what its exact place in the series, are points not yet known. I think it probable, however, that this is about Coal XII.

Anticlinal B of *Basin* 8.—Three other subordinate anticlinals occur in this synclinal belt, which we have called Basin No. 8. The most Southern of these seems to take its origin, or to have its E. end, on the N. slope of Green Ridge, between Shamokin Creek and Buck Run, where it forms, indeed, an independent lower crest. Crossing Buck Run about 600 feet S. of its junction with the Shamokin, the axis, ranging along the same line of crest, crosses Gerhart's Run about half a mile above its mouth, and Mowray's Run, 2000 feet S. of its junction with Carbon Run. Beyond this point the anticlinal ranges through the Scott Tract into the N. flank of the Mahanoy Mountain, expiring in a depressed flexure high upon its slope near the W. end of the high knob which the mountain exhibits S. of the head of Carbon Run.

Coals exposed along Axis B *of Basin* 8.—At the passage of Buck Run across this anticlinal, the large coal, No. VIII., ascending from the mouth of Buck Run, arches the saddle above the water-level of the ravine, but is not denuded on the ridge either E. or W. of it; but, basining between this axis and the main anticlinal No. 7, it outcrops to the N. of the latter. We know but little of the coal brought to the surface by the axis at its intersection with Gerhart's Run, but apparently it is Coal X. Further W., a coal, deemed by us to be Coal X., has been shafted near the axis both E. and W. of Mowray's Run. Reaching Section No. 2, W. of Shamokin Gap, the ascent of this axis is discernible in the rising out of Coal VIII. to the surface, pretty high towards the foot of the mountain. This is on the Scott Tract, beyond which no systematic diggings have been yet undertaken in quest of coal.

Anticlinal C *of Basin* 8.—Parallel with the preceding anticlinal, and at an average distance of 800 or 900 feet N. of it, ranges another long straight wave in the Coal-measures. This appears to commence towards the E., near the base of Green Ridge; or, more precisely, it first shows itself in the W. bank of the Shamokin Creek, a little W. of the mouth of Buck Run, where the next coal over the large bed just peeps to the surface, arches, and disappears again. From this spot the axis is traceable W. to where it is intersected by Gerhart's Run, and again by Mowray's Run, and still further to our Section-line W. of Shamokin Gap. Beyond this point it encroaches, like the preceding axis, upon the long sloping flank of the Mahanoy Mountain, and probably at last draws near to, or even merges into, its crest. If thus prolonged, its termination must be somewhere near the bend of the crest opposite the extreme source of Carbon Run. Like nearly all the axes S. of it, this anticlinal flattens its S. dips rapidly as it obliquely ascends the Mahanoy Mountain. It there however preserves, or even increases, the steepness of its N. dip.

Coals exposed along Axis C *of Basin* 8.—There can be little doubt that the coal brought to the water-level of Shamokin Creek by this anticlinal is No. IX. of our series, or the next seam above the large one, No. VIII. Just W. of Mowray's Run, coal has been opened at the axis, which is possibly Coal VIII. itself, though of the identity of this I feel uncertain. Further W. again, at the section through the Scott Tract, about the same portion of the series is again exposed upon the axis, and beyond this we know nothing specifically about it.

Anticlinal D *of Basin* 8.—Another shorter anticlinal occurs in the same belt in the W. part of Basin No. 8, also parallel with the rest, and S. of Carbon Run. At our W. section through the Scott Tract, it lies about 900 feet N. of axis C, where it occupies the crest of a flat hill, or a swell at the foot of the mountain. It is possible, judging from the topography, that this axis exists as far E. as the crest of the hill next W. of Gerhart's Run, but we have no specific proofs of its course either E. or W. of the section, where we have intersected it; we can only infer, from certain topographical features, that, like the many axes S. of it, it advances W., encroaching upon the flank of the Mahanoy Mountain, until it expires somewhere N. of the summit. We are equally ignorant at present as to what coal this axis brings to the surface at our cross section, but we are entitled, from several considerations, to infer that it must be a bed high in the White-Ash series, perhaps Coal X. or XI.

OF THE SUBORDINATE BASINS INCLUDED IN BASIN 8.

Owing to the oblique position, in the general Basin No. 8, held by the anticlinal of Jamie's Ridge, this general basin is naturally subdivided into two portions—one extending from the Catawissa Road to about the mouth of Quaker Run, and the other from Mount Carmel to the place of disappearance of the Red Ridge axis somewhere on Carbon Run. I shall now pass to the consideration of these synclinals, and to an account of the coal strata which they contain.

Basin a of Basin 8.—The Eastern division of Basin 8, which we shall call Basin *a*, commences in a narrow point of the Coal-measures, about 1000 feet E. of the Catawissa Road, the trough originating on the spur embraced between the two coves of Umbral red shale which there head up into the Shamokin Mountain. Crossing the road, this synclinal rapidly assumes the form of a regular valley, which, descending W., is watered for nearly its whole length to the point of Red Ridge, first by the middle, and then by the Main Shamokin Creek. Contracting as it goes W. of the N. branch of the Shamokin, it soon loses altogether the structure of a valley, and the only streams which traverse it are Cedar Run, and the feeble N. tributaries of Quaker Run.

Coal-measures in Basin a of Basin 8.—From the points already indicated on Mine Ridge and Red Ridge, where the upper beds of the Seral conglomerate are saddled over by the lowest productive coal-seams, the crests of these two ridges, and of Jamie's Ridge, constitute the natural limits of this basin. Mention has been already made of the Coal-measures exposed at the borders of the basin by these anticlinals, and it now only remains to state what higher coals have been preserved from denudation in the more central or deeper parts of the trough. For the first mile W. of the Catawissa Road, it is probable that only the lower White-Ash coals, or those beneath the large bed, No. VIII., have any existence in the basin; but further along the valley, probably at our Section No. 8, and certainly at Section No. 7, we have the fullest evidence of the presence of nearly the whole of the upper White-Ash group. From near the point of Mine Ridge to near the termination of Red Ridge, the average depth of the basin is probably nearly constant, the gradual rise of the Jamie's Ridge axis apparently compensating for the slow subsidence of that of the Red Ridge. At the North Branch of the Shamokin Creek there are probably three or four coals in the basin higher than Coal VIII., but the width between the outcrops of the uppermost is of course inconsiderable. In the neighbourhood of Quaker Run and Little Quaker Run, the basin contracts to not more than one-half, or even one-third, of the breadth which it has E., yet it retains, by the subsidence of all the anticlinals towards this central part of the coal-field, the same upper White-Ash coals; but precisely what coal it is which basins on the ridge a few hundred feet S. of Hornberger's, it is impossible to say until more mining has been done.

Basin b of Basin 8.—Crossing the anticlinal of Jamie's Ridge, we proceed, in the next place, to trace briefly the coals left in Basin *b* of Basin 8, or that embraced between Jamie's Ridge and the Mount Carmel anticlinal as far as Green Ridge Gap. At the narrow Eastern point of this synclinal belt, or the little plateau of Mount Carmel, the first coals under the surface are those, it would seem, which next overlie the thick bed, No. VIII., and the same may be said of that part of the basin which extends from the North Branch of Shamokin Creek to Quaker Run. Indeed, it is probable that the surface coals of the middle or synclinal part of the basin, throughout nearly its whole length to the mouth of Quaker Run, are those embraced between Coal IX. and Coal XII. inclusive; while W. of Quaker Run, with the disappearance of Jamie's Ridge axis, the bed of the basin, occupied by the Shamokin Creek, embraces three or four still higher coals. That this is true may be seen by inspecting our Main Shamokin cross-section, which exhibits the very highest coals of the district, dipping in synclinal posture in the centre of this trough. Beyond this intersection of the basin by the Shamokin Creek, N. of Buck Run, it is not practicable, in the present undeveloped state of the ground, to attempt a detailed tracing of its coal-beds. It will suffice to state that, following the trough W. to Carbon Run, we must there meet with lower and lower Coal-measures gradually coming up, as successive anticlinals—such as B, C, and D of the basin we are in—intrude themselves and give a Westward lift to all the rocks.

Having already specially indicated, as far as known, what coal-beds are brought to the surface by these subordinate anticlinal waves which lie between the two long axes No. 7 and No. 8, and having thus shown incidentally very nearly what the uppermost coals must be which they retain between the various cross-sections of Buck Run, Gerhart's Run, Mowray's Run, and those through the Scott Tract, it would be superfluous and tedious to attempt to define in more detail the uppermost coals of these narrow troughs. I shall therefore here terminate my description of Basin No. 8, and pass to the consideration of the anticlinal No. 9, or that of Coal Run Ridge, and of the basin next S. of it, or that of the North Branch of Shamokin Creek.

ANTICLINAL NO. 9, OR THAT OF COAL RUN RIDGE.

The last or most Northern main anticlinal of the coal-field is that of the mountain-spur of the Shamokin Mountain, called the Coal Run Ridge, which is the third of the chief mountain anticlinals of the proper Shamokin Basin, not counting the bounding one of the Locust Mountain. The three large anticlinal waves—that of Mine Ridge, of Red Ridge, and this of Coal Ridge—distribute the Coal-measures of the E. half of the Shamokin Basin into four very symmetrical synclinal troughs, the most Northern of which is the Coal Run Valley, embraced between this high axis and the monoclinal crest of the Shamokin Mountain. It will be observed, upon inspecting the Map, that these three mountain-spurs are successively longer the further N. they are, the Coal Ridge being longer than the Red Ridge, and this last longer than Mine Ridge. This interesting fact lends some countenance to the view which would make the Mine Ridge anticlinal, or No. 7, terminate near the North Branch of Shamokin; and that of Red Ridge, or No. 8, end either near the source or the mouth of Quaker Run. But even if this view be the correct one, the assumption that I have made, that these two axes are prolonged much further W., does not seem to vitiate any practical deductions. (The reader will gain a clearer conception of the relations of the coal strata in these ridges and basins, if he will here consult the 4th Section on Plate IV. of the Coal Sections, or that E. of Mount Carmel.)

The Coal Ridge axis enters the coal-field through the outer flank of the Shamokin Mountain, at a recess in its crest S.E. of the terminating knob of the Coal Run Basin. This recess is really an anticlinal cove in the Red Shale, but shorter and less excavated than those through which the Red Ridge and Mine Ridge axes enter the basin. For about 3 miles W. from the synclinal knob, the crest of the anticlinal wave displays an extensive denudation of the Coal-measures, the summit of the mountain exposing, over an average width of more than 1000 feet, no coal-bearing rocks, but only the Seral conglomerate. But within less than half a mile W. of the passage of the centre turnpike across the ridge the axis commences rapidly to decline, and here the lower productive coal strata close over the conglomerate. Near this point the structure of the mountain becomes a little complicated, two additional anticlinals, one S. and the other N. of the main axis, appearing on its flanks, and running closely parallel with it. The main axis of the ridge, intersected by our shaftings, and clearly proved in position by openings in the coal-beds, and by observation upon the rocks, declining rapidly in its degree of flexure at Coal Run, crosses the valley of that stream only a little above the old gangways at the water-level in its W. bank. Here the S. dip from the axis is between 25° and 30°, while on the N. side it is nearly flat, from the lifting influence of the saddle next N. of it. Westward from Coal Run the main anticlinal very rapidly subsides, seeming hardly to reach the ravine of the Luke Fidler Colliery. Throughout the E. half of Coal Ridge the S. leg of the arch appears to be materially steeper than the N. one, but along the W. half to Coal Run the proximity of the waves upon its flank seems to interfere with the preservation of this form, the N. axis, or B of Axis 9, becoming soon a more inflected wave than the main one of the crest of the mountain. From a point about due S. of the passage of the turnpike across Shamokin Mountain, the subordinate S. axis of Coal Ridge, or A of Axis No. 9, seems to constitute a summit about as high as that of the main axis, and to form indeed the principal crest towards the end of the ridge. An inspection of Section 1 of Coal Run Basin shows the arch of Coal Run Ridge flat, or even slightly concave, on its summit, a structure which arises from the presence of two anticlinals, the main one, No. 9, producing the S. dip, and the auxiliary one, B of Axis 9, the N. dip. The S. axis, the feeblest of these, seems to expire altogether before reaching the gap of Coal Run, while the Northernmost is here even somewhat stronger than the chief or middle one, and prolongs itself considerably beyond it to the W. How near to the town of Shamokin this actually approaches, we are unable yet to say.

COAL-MEASURES EXPOSED ALONG THE COAL RIDGE ANTICLINAL.

The first productive Coal-measures over the Seral conglomerates appear to saddle the crest of Coal Ridge about half a mile W. of the centre turnpike. From this point W., higher and higher strata undulate across the complex anticlinal, until, at Coal Run Gap, the coals which rise in the double arch above the water-level are probably as high in the series as Nos. X., XI., and XII.

BASIN No. 9, OR THAT OF THE NORTH BRANCH OF SHAMOKIN.

Between the Red Ridge axis and the anticlinal of Coal Ridge occurs a long and quite regular synclinal trough in the Coal-measures, descending W. from the middle of the more Northern spur in which the Shamokin Mountain terminates E. The chief part of this spur, which, near its junction with the main mountain, is a high flat table-land, is covered only with the different members of the Seral conglomerate, no productive Coal-measures appearing to exist upon it further E. than about one-third of a mile E. of the Ashland and Catawissa Road. There the true coal-basin begins in the middle of the flat synclinal table-land. Rapidly expanding, the N. edge of the true coal-basin presently gains the monoclinal crest of the Shamokin Mountain, and pursues it to the head of the recess at which the Coal Run axis enters it, beyond which the boundary follows the S. side of the flat summit of Coal Ridge to the point half a mile W. of the Centre Turnpike, where, as already intimated, the conglomerates are saddled over by the more productive coal-rocks, from which point to Coal Run Gap the N. limit of the basin must be considered as the chief axis of Coal Ridge, whichsoever this may be along the different portions of its undulated summit.

Following next the S. limit of the productive coal-basin, we still find the line crossing the Catawissa Road a few hundred feet N. of the crest of Red Ridge, and gradually ascending that crest until, at a distance of perhaps three-fourths of a mile W. of the road, it turns across it, and is joined by the N. edge of the same coal-rocks belonging to Basin No. 8, south of it. From this point of the first saddling of the Coal-measures the true S. limit of Basin No. 9 is the anticlinal axis of Red Ridge, approximately coincident with the crest of the mountain. To the W. of the notch in the end of the ridge, at the passage of the North Shamokin Creek, no well-defined topographical feature bounds the basin on the S. as far forward as Coal Run, unless, indeed, we generalise the range of hills passing N. of Hornberger's into a sort of broken ridge. The structure of the general synclinal belt between Axis No. 8, south of Shamokin, and the line of extension of the Coal Ridge anticlinals, is so undulated W. of Coal Run Gap, especially near Shamokin, there being in this interval at least four anticlinal waves, that it is not expedient to consider Basin No. 9 as really prolonged any further in that direction.

OF THE COAL-MEASURES PRESERVED IN DIFFERENT PARTS OF BASIN No. 9.

Though this basin of the N. branch of Shamokin Creek is from its Eastern end to Shamokin Creek remarkably regular and free from undulations, yet it is not entirely exempt from them; and for the sake of accuracy in my description of the distribution of the coal-beds within it, an allusion to the positions occupied by these subordinate flexures is indispensable.

First, there occurs in the N. slope of Red Ridge, not 1 mile E. of the gap of North Shamokin Creek, a gentle undulation, exhibiting a very feeble S. dip, with a steeper N. one, the axis being about 800 feet N. of the main anticlinal of the ridge. The effect of this is to lessen the number of separate coal-seams in this part of the mountain, while it multiplies their outcrops. How far this small flexure, which properly belongs to the anticlinal wave of Red Ridge, extends E. and W. along its flank, it is impossible in the present unopened condition of the basin to ascertain.

The second and only other known flexure or disturbance within the North Branch Basin occurs at the S. foot of Coal Ridge, near the Centre Turnpike. A perpendicularly-dipping coal, shafted both E. and W. of the road, implies the proximity of a sharp crushed axis S. of it; and the existence of apparently the same coal dipping Southward at a very high angle some 300 feet further N., by indicating a squeezed basin, supports this view of a compressed anticlinal. To what distance this acute flexure extends low on the slope of the mountain we are unable to say, but it seems to have no existence 1½ miles to the Westward, where all the coal-beds of the slope and base of the ridge have been carefully opened and proved, and where only undisturbed Southward dips prevail.

That the lower Coal-measures actually pass to the Eastward of the Catawissa Road is obvious from the materials on the surface, and from certain shaftings on two or three coal-beds in the neighbourhood of the turnpike. That the Coal-measures also rise high upon the summit of Shamokin Mountain, is a fact equally well established by actual digging along its crest W. of the road. Descending along the basin, we shall find, of course, successively higher coals basining out to meet us as we advance down the bed of the valley ; but no developments have been yet made to show at what point the several lower and middle White-Ash seams have their Eastern spoon-shaped terminations. From all the data afforded by the developments made in shafting, from the gap of the North Branch in Red Ridge to Coal Run and the Shamokin Creek, we are entitled to infer that the uppermost coal-seams remaining in the centre of this synclinal belt, where the North Shamokin Creek turns to pass out of it, are those which overlie the large Coal-bed, No. VIII., perhaps as high in the series as Coal X. or XI. ; that those which lie highest in the basin N. of Hornberger's are the Coals XI., XII., and possibly XIII. ; and that those which we meet with at the passage of Coal Run across the basin are the Nos. XIII. and XIV. of the series. It is not practicable, in the present infancy of mining in the district, to trace the distribution of the coals in this synclinal range with any more precision.

ANTICLINALS IN THE PROLONGATION OF BASIN 9, SOUTH OF SHAMOKIN.

Four anticlinal undulations, as already intimated, occupy the width of this general synclinal belt opposite Shamokin between the leading anticlinal No. 8 and the prolongation of those of Coal Ridge. That these are in some sense subordinate to this synclinal tract or basin, must be inferred from the circumstance that they nowhere lift out the lower White-Ash coals, neither of them bringing to the surface anything deeper seated than Coal XII.

Axis A *of Basin* 9.—The first or most Southern of these flexures has its E. commencement probably about opposite Coal Run Gap, for S. dips connected with it are visible in two or three coal-beds, shafted at the N. foot of the narrow neck which separates Coal Run from Quaker Run. From this point it ranges Westward to the valley of the Shamokin through the depression between the two synclinal summits of the mass of land enclosed between the Shamokin and Coal Run, and crosses the Shamokin Valley about 400 feet S. of the Furnace. Its course Westward of the valley is between two similar knobs, the prolongations of the same synclinal basins. Indications of this axis occur about 1400 feet N. of Carbon Run, and opposite the mouth of Gerhart's Run, beyond which, though it is probably prolonged for a good distance, we have not traced it. The road from Shamokin to Trevorton probably passes for some distance along the crest of this anticlinal near the head of Carbon Run ; but in the present unopened state of the district it is not expedient to state this too positively.

Coals exposed at Axis A.—The lowest coal denuded at the water-level on the arch of this anticlinal is apparently the Coal XIV. of our Shamokin series, though I would not at present be very positive in my count to within one coal. Three other seams of workable dimensions overlie this bed of the anticlinal axis, and the uppermost of these, by my estimate Coal XVII. of the basin, outcrops in synclinal manner all round each of the two synclinal ridges which bound this axis. Each basin terminates about half a mile E. of the Furnace. Of this we feel assured, inasmuch as the seam has been carefully traced by shaftings conducted by Patrick

Daly, the most skilful practical explorer of coal, by digging, in all the anthracite coal region. This anticlinal appears to subside gradually in going Westward.

Axis B *of Basin* 9.—North of the preceding about 1000 feet ranges parallel with it another shorter axis, commencing apparently W. of Coal Run, crossing the valley of Shamokin Creek some 600 feet N. of the furnace, and dying out probably Westward of Carbon Run. We only know it distinctly where the denuded valley of the Shamokin exposes it. It lifts just the same coals to the surface, though not quite as high as are brought up on the axis S. of it. This anticlinal would appear to sink Eastward.

Axis C *of Basin* 9.—The third anticlinal of the group is a considerably longer one, being traceable from near Coal Run to the vicinity of Furnace Run, W. of Shamokin. The position of this saddle is a little S. of the North-dipping openings on the uppermost coals of the Luke Fidler Tract, just N. of the Shamokin Road. Crossing from the valley of Coal Run, it goes through the narrow hill which divides this from the Shamokin Valley, and crosses the latter just 900 feet S. of the railroad bridge over Coal Run. About one-third of a mile W. of the mouth of Carbon Run the axis has been proved by shaftings nearly 300 feet S. of the Trevorton Road, but W. of the section there we have no means at present of tracing it in its prolongation. The sharpness of the flexure, however, its N. dips being 70° and its S. 45°, implies that it ranges on for some distance. This axis, in fact, evidently rises Westward.

Like the two preceding saddles, this flexure elevates to the water-level of the Shamokin Valley Coal-bed XIV. of the basin.

Axis D *of Basin* 9.—The fourth and last flexure of the group, a shorter and feebler one than the last, is that of the beautifully-developed arch just S. of Coal Run, at the town of Shamokin. Indications of it may be detected as far Eastward as the ravine of the Luke Fidler Colliery, and its influence upon the strata is conspicuous E. of the old sawmill pond on the railroad. It crosses the valley of the Shamokin Creek, and indeed appears to be three times intersected by the stream in its windings. Whether this and the anticlinal developed by coal-shaftings on Furnace Run 1200 feet W. of its mouth, are the same, is at present doubtful, since that flexure lies 200 or 300 feet too far N. for a parallel prolongation of the saddle next S. of Shamokin.

Being a feebler anticlinal uplift than either of the three preceding axes, the N. dips from it are comparatively gentle, not exceeding 30°; the S. limb of the arch, however, disappears at an angle of 60°.

The lowest coal elevated to the level of the railroad upon the summit of this arch is apparently No. XII. of the Shamokin series; possibly it is No. XIII. A careful tracing of the ground Eastward indicates this coal to be the same as the Southern or upper one of the Luke Fidler Ravine. Our cut exhibits the size and divisions of the Luke Fidler coal, so called.

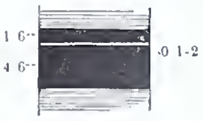


FIG. 242.—Luke Fidler Coal-seam.

Looking at the configuration of all five of the anticlinal waves which cross the Shamokin stream between the mouth of Coal Run and that of Buck Run, we are struck with the accordance which prevails among them all except the most Northern, or that last described. Each is a little steeper on the N. leg of the arch than on the S.; their distances asunder are nearly equal, and they are remarkably parallel. The last of the group, however, or that nearest Shamokin, betrays the opposite law of curvature of its arch, the S. limb being the steep one, and the N. the flat. Such, too, is the form of the flexure developed in the coal-shafts on Furnace

Run. It is worthy of note, that this flattening of the N. dip takes place only in the Northern flexure, or the first one which begins to feel the influence of the general uprising of the Northern side of the basin, or the strata of the Shamokin Mountain.

When we embrace in one comprehensive view all the numerous anticlinal flexures, twelve at least in regular series, which occupy the undulated synclinal valley of the Shamokin Coal-field in the region of the Shamokin Gap, we are struck with the circumstance, that while all the Southern ones, or those which enter the long Northern slope of the Mahanoy Mountain, exhibit a progressive flattening of their Southern sides, lifted, as it were, by the general uprise of the strata of the S. side of the coal-field, the middle group observes the normal law of the Appalachian anticlinals, which is to have their Northern incurvation steeper than their Southern ; and that the Northern set, or all those which range at the base or on the flank of the Shamokin Mountain, reversing the configuration of those of the Mahanoy Ridge, have their S. slopes the steepest, and their N. ones flattened, as if raised by the opposite or S. dip of the Northern side of the great trough. This modification of the form of the subordinate flexures, by the position they occupy in the general basin, is not confined to this Western end of the Shamokin Coal-field, but prevails everywhere in the more undulated districts of the entire coal-region. I conceive it to be in the strongest manner significant of the mode of origin of these lesser undulations, which I regard not as flexures pervading the whole thickness of the earth's once flexible crust, such as unquestionably the great Appalachian anticlinals are, but as more superficial corrugations produced in a secondary manner within the wide crust-waves, by the plicating action of the lateral forces engendered upon the contraction of the area of the upper strata, by the approximation of the sides of the great troughs into which the crust was heaved.

BASIN No. 10, OR THAT OF COAL RUN AND ITS INCLUDED ANTICLINALS.

The Northernmost of the sub-basins of the Shamokin Coal-field is that of Coal Run, bounded on the S. by the complex anticlinal of Coal Ridge, and on the N. by the monoclinal crest of the Shamokin Mountain. As a distinct synclinal trough, this belt is not prolonged much to the W. of Coal Run Gap, for the disappearance of the Coal Ridge anticlinals E. of Shamokin, and the introduction of other flexures N. and W. of that town, conspire to destroy the simple basin structure which it possesses further E., and to compel us to adopt a new classification of the coal-field W. of Shamokin Gap, and N. of Carbon Run. For convenience, however, we will extend our description beyond the proper Coal Run Basin, or from the synclinal mountain-knob in which it commences N.E. of Mount Carmel, to the notch in the mountain by which the Shamokin Creek passes out of the coal-field. Thus limited, it may be defined as a straight basin about three-fourths of a mile in breadth in its central widest portion—with a gradual descent to the Westward—of a simple synclinal structure at its Eastern end—undulated in its centre, along its middle section, by a sharp straight anticlinal wave—and undefined in its Western end by any Southern anticlinal boundary.

As in similar former instances, it will be expedient, before entering on any statement of the Coal-measures found within this basin, to trace the subordinate anticlinals which occur within it, especially a long and very regular one which ranges near the centre of the trough.

Anticlinal A *of Basin* 10.—This flexure of the strata undulating the bed of the trough, which but for it would be a remarkably symmetrical synclinal wave, seems to commence at the E. near the Centre Turnpike, and to pursue a straight course a little N. of Coal Run. Crossing our several exploratory shafts in its progress along the valley, its position has been accurately determined. Converging a little upon the Northern axis of Coal Ridge, or *b* of Axis 9, it passes N. of Coal Run Gap about 1200 feet from that axis. Here leaving the valley, it takes the summit of an irregular tableland, and afterwards the crest of a ridge into which this is prolonged, in the very point of which, and not more than a few hundred feet from the E. edge of the village of Shamokin, it displays itself in a regular arch of coarse sandstone. If it range so far, it must pass a little N. of the village. Except near Coal Run Gap, which is not far from the middle of its length, this flexure is everywhere much steeper in its Southern limb than in its Northern, the dips in the former, for some 2 miles W. of the Centre turnpike, being between 55° and 75°, while the N. dip only amounts to about 10°. So likewise, near Shamokin, the S. leg of the arch dips 30°, and the N. leg only 10°. Opposite Coal Run Gap, however, where its distance from the Northern axis of Coal Ridge is less, the influence of this is to flatten the S. dip to 20°, while the N. dip here amounts to 30°. The direction of this wave is singularly parallel with that of the crest of the mountain N. of it.

The influence of this central anticlinal in lifting the bed of the coal-basin, and in throwing out, or causing, by exposure to denudation, the loss of some of the higher coals which would otherwise have occupied the bed of the valley, is not to be overlooked, and it behoves us to ascertain, if possible, what the highest beds are which have been left to saddle over it at the lowest water-levels which intersect it. To determine this for all parts of the basin would not be an easy task, but expensive experimental shaftings, conducted under my direction, have enabled me to ascertain that, in all probability, the axis north of Coal Run Gap just lifts to the crown of the hill, through which it passes, the Coal X. of the basin. But whether or not precisely the same part of the Coal-measures is exposed all along to the Eastward is doubtful, since a mere difference in the steepness of the flexure, and therefore in the depths of both the subordinate troughs into which it divides the basin, may make a material difference in the number of coal-beds preserved or washed away through its agency. I believe, however, that very nearly the same Coal-measures will be found to range along this axis throughout almost its entire length from W. of the Turnpike to Shamokin village.

Axis B *of Basin* 10.—Another secondary anticlinal, originating at the base of the Shamokin Mountain N.E. of the village, lies about 600 feet N. of this last. This flexure is distinctly to be seen on both sides of the Southern entrance of Shamokin Gap, where the bridge crosses the stream, there forming a beautifully-regular low arch in the coarse sandstone and Pea-conglomerate which overlies the Coal X. or XI. of the basin. It is indicated, likewise, on our main Shamokin Cross Section, 1000 feet or so N.E. of the upper edge of the village. Beyond this, to the Eastward, it seems by its bearing to encroach slightly upon the flank of the mountain. Between the village and Shamokin Gap, we may perceive, in the steepness of the hill-side N. of the road, the influence of this axis on the topography. How far to the Westward of the gap this flexure extends I have at present no data for determining, but as the flexure is a gentle one, we may infer that its length is not great.

The reader will be much assisted in following the foregoing description of the numerous secondary anticlinal flexures and basins of the Shamokin Coal-field, by consulting, at the same time, the Map of the coal region, and the 5th and 6th Sections on Plate IV., or that through Shamokin, and that across the head-waters of Gerhart's Run.

DESCRIPTION OF THE COAL-MEASURES IN COAL RUN BASIN AND AT SHAMOKIN GAP.

The fine natural section, rendered still clearer by mining, of the Shamokin Gap, a cut of which is here presented, illustrates well the Coal-measures of the Shamokin Mountain and the Coal Run Basin.

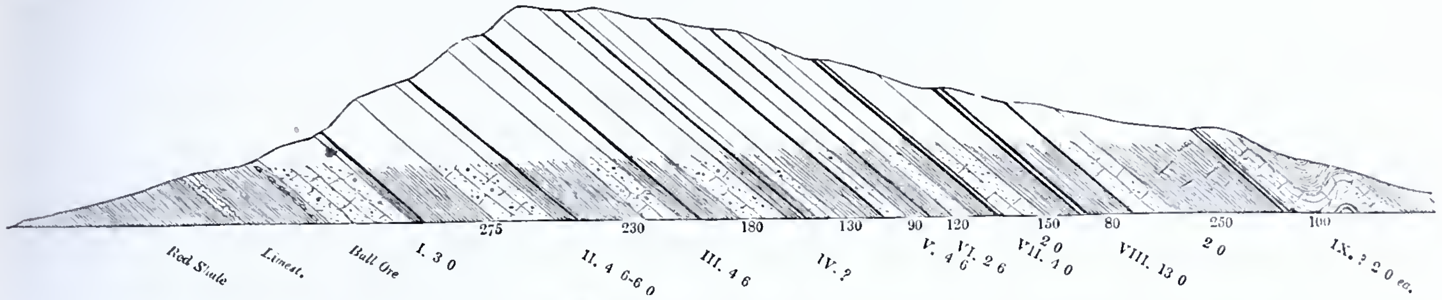


FIG. 243.—Section of Shamokin Mountain at Shamokin Gap, looking E.—1 *inch* = 400 *feet.*

The productive Coal-measures in this basin appear to begin on the E., in the very summit of the synclinal knob in which the basin terminates, and the first or lowest coal of the conglomerate series occupies the crest, or even a bench, high on the N. slope of the Shamokin Mountain, for the chief part of the distance to the Shamokin Gap. Coals have been shafted in these positions just W. of the summit-level of the Centre Turnpike. The same lower coals, or those within the coarse conglomerate, must outcrop on the broad summit of Coal Ridge for a distance to the E. of the turnpike; but the more productive, or middle and upper Coal-measures, as already intimated, first saddle the crest of the mountain about half a mile to the W. of the road. The 2d coal-seam generally outcrops in a bench either on the very crest of the mountain, or just a little S. of it, the 3d in another bench usually very high on its S. slope, and the 4th and 5th in terraces still lower down. All these coals lie between massive strata of the coarse conglomerate rock, of which the main body and crest of the Shamokin Mountain consist.

Coal No. I. is nowhere more than 2½ feet thick; Coal II., where opened, contains in some places 6 feet of coal; and Coal III., about 125 feet S. of it, contains, with a thickness of 8 feet, often 6 or 7 feet of good coal. Coal IV., at a distance of 100 feet S. of the last, exhibited in the shafts opposite Coal Run Gap a thickness of 6 feet, and promised to yield about 4½ feet of coal; while Coal V., distant from the Coal IV. only 75 feet, with a dip of 45° to the S., showed a thickness of 2½ feet at the points where it was best exposed. Nearly all these beds, apparently in full development on our Sections N. of Coal Run Gap, are more or less crushed by mechanical pressure at the gap of Shamokin Creek further Westward. Comparing this group of five coals within the Seral conglomerate, we may either regard the lowest, or No. I., as the equivalent of the outside coal of Trevorton or Zerbe's Gap, called O of that series; or we may consider the small 5th seam as an additional upper coal entering the conglomerate group Eastward of the Shamokin Gap, and suppose the O of Trevorton to thin out altogether before coming so far E.

Ascending in the series, the next group of coals consists of those which overlie the coarse conglomerates of the mountain, which are limited upward by a well-marked little conglomerate stratum of small pebbles. This group generally embraces about four workable seams, and in all six coals of notable size. The lowest of these usually have their N. outcrops, or the N. limits of their special basins, at the S. foot of the steep slope, or upper part of the mountain; in other words, at the upper limit of the long inclined plane which rises from the bed of the valley to the first abrupt acclivity of the ridge; each such outcrop is indicated by an obvious depression or shelf upon the side or at the base of the mountain. Descending into the bed of the basin, these upper coals, or those of the softer Coal-measures, probably six or seven in number, where the whole are present, rise again in the anticlinal flexure of the middle of the valley, the upper ones cropping out, and the lower ones arching the axis. Taking another dip, they trough themselves a second time in the S. or immediate valley of Coal Run, to rise a second time in the N. flank of Coal Run Ridge, either to outcrop there, or to saddle in turn the axes of that mountain, according to the part of the basin across which we trace them. These coals do not appear above the water-level of Coal Run in the gap at the W. end of Coal Ridge, for the little conglomerate surmounting them there forms the interior stratum of the flat anticlinal arch. To the Eastward they rise and lap over the axis or outcrop on both slopes of the ridge. They may be reached by the ordinary method of mine slopes, by stationary power, for a distance of some 3 miles Eastward from Coal Run Gap. The middle large coals of this group, No. VIII., for example, outcrop on the summit of the Anticlinal Mountain, probably between our Sections No. 4 and No. 3 of the Coal Run series. The lowest coal of this middle group, the equivalent of No. V. of the Trevorton Scale, outcrops at the foot of the upper steep declivity of the Shamokin Mountain, while on Coal Run Ridge it lies saddled over by the beds above it, until we reach the neighbourhood of the Centre Turnpike, where it comes out to the day near the anticlinal axis. It is probable that this bed does not basin out Eastward in the valley, until we reach a point a mile at least E. of the turnpike.

The next large coal of the group, No. VIII. of the whole basin, containing about 6 feet of good coal at the points where it has been proved or mined, is one of the productive beds at the Shamokin Gap. To this succeeds Coal IX., apparently the Twin Coal of Zerbe's Gap. In the basin before us this is in reality two coals, divided by an argillaceous sandstone or hard sandy shale, varying from 15 to 18 feet in thickness ; the lower bed at the Shamokin Gap being 6 feet thick, while the upper is usually about 7 feet ; but N. of Coal Run Gap the upper bed has 8 feet of coal in the shafts, and the lower about 3 feet. These dimensions are the smallest under which this double coal usually presents itself, and in the basin South of the Coal Run Valley it has in some places 14 and even 20 feet of total thickness of coal, with a dividing rock thinned down to only a few inches of slate. On the Sunbury Railroad E. of Shamokin, and therefore S. of the Coal Run Basin, the coal-seams VIII. and IX. have their dimensions and divisions shown in the annexed cut.

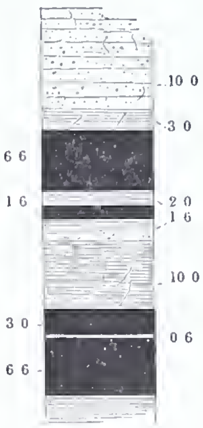


Fig 244.—Coals VIII. and IX. on Sunbury Railroad E. of Shamokin.

The upper or third group of coals, or that which overlies the so-called little conglomerate, embraces, where the formations are fullest in the coal-field, about five seams, of a thickness of 3 or more feet each ; some of these take their place in the middle of the Southern trough of the Coal Run Basin, or that between Coal Ridge and the anticlinal axis of the middle of the valley ; but they cannot ascend the basin Eastward any considerable distance beyond where they have been shafted on and proved, between our Cross Sections Nos. 2 and 3 of Coal Run, or perhaps a mile above Coal Run Gap. The lowest beds of this group arch over the flat anticlinal of Coal Run Ridge at Coal Run. The upper seams pertain probably to the base of the Red-Ash Coal-measures of the Pottsville Basin, and the lower ones are on the horizon of the Grey-Ash coals. It would appear that there are in all, in the deeper parts of the Coal Run Basin, at least some fifteen or sixteen coal-seams of notable dimensions, more than half of which are of a size and quality fitting them to be extensively mined.

Estimate of the Coals in Coal Run Basin.—The Coal Run Basin has a length of rather more than 4½ miles, and an average breadth, measured from the anticlinal summit of Coal Run Ridge to the crest of the Shamokin Mountain, of about 4500 feet. In estimating the extent of each separate coal-bed within this basin, it must be borne in mind that those which are undermost in the strata occupy the whole of this breadth, and range lengthwise along its entire course. Each of these, therefore, fills an area of at least 3 square miles. The other coals, which are higher in the series, are somewhat more circumscribed as respects both the breadth and the length of the troughs which they form, for, reposing in concentric basins, their outcrops or margins lie successively nearer and nearer the bed of the valley. Nevertheless, I am disposed to compute the average areas of the large coals which next overlie the conglomerate series of the mountain at not less than 2½ square miles. These have their Northern outcrops close under the base of the steep flank of the Shamokin Mountain on the one side of the basin, while on the other, in Coal Run Ridge, they spread to the anticlinal itself, excepting only where this lifts to the surface the mountain conglomerate in the vicinity of the central turnpike and Eastward. As to the space occupied by the upper coals—namely, those exposed in drifts and shafts in the gap of Coal Run Ridge, near the anticlinal—a careful tracing of their outcrops or edges clearly shows that these, in their turn, cover an area of at the least 1½ square miles.

Combining with the foregoing elements of area or superficial extent, a review of the available thicknesses of the several coals, it will be easy to frame a very reliable approximate calculation of the quantity of coal contained in each bed or group of beds, and compute with some precision the total amount embraced within the whole basin.

In passing to the consideration of the dimensions of the various coal-beds of this basin, I wish it to be distinctly known that the measurements here given relate to the good or available coal which they contain, as deduced from a comparison generally of several or even many openings made on each seam at distant points.

To present the full thicknesses of the beds without adequate reduction being made for the slaty coal, slate, and fireclay generally contained in more or less amount in all our anthracite seams, is to commit a serious and unwarrantable exaggeration. Adopting the ascending order, we begin with

The 1st Coal.—This seam has its outcrop near the very crest of the Shamokin Mountain, being the lowest of the conglomerate series. As exposed by shafting, it is about 2½ feet thick, and may contain 2 feet of good coal.

Though it underlies the entire basin, and may very possibly expand in some localities to more profitable dimensions, I shall exclude it altogether from my estimate of the workable coal. The next discovered bed, which I shall call

The 2d Coal, is a mass of excellent fuel, measuring between its fireclay floor and its roof of slate about 7 feet. It contains, where it has been opened, 6 feet of marketable coal. This bed has its N. outcrop on the brow of the mountain, and underlies the whole extent of the basin.

The 3d Coal outcrops on the next conspicuous bench or terrace on the S. flank of Shamokin Mountain, about 125 feet further S., and basins with the other conglomerate coals, the two below it, and the two above it, under the whole breadth and length of the Coal Run Valley, and also the valley of the North Branch of Shamokin Creek. This coal, on Shamokin Mountain, measures 8 feet between a floor of fireclay and a roof of slate, contains a dividing-slate of not 6 inches in thickness, and possesses as much as 7 feet of good coal.

The 4th Coal has its outcrop on the Shamokin Mountain, usually about 75 or 100 feet S. of the 3d, and on a less conspicuous bench. It there shows an average thickness of about 6 feet, but usually contains a thin band of slate, and frequently a layer of rough and slaty coal, which reduce its available productiveness to about 4½ feet. On the most Western line of shafts, near the outlet of Coal Run, it exposes a thickness of 7 feet, and of this 6 feet is fair coal. I shall count it at 4½ feet.

The 5th Coal is distant from the 4th not more than 75 feet, dipping 45° to the S. with the rest. It holds a slightly lower depression on what may be viewed as the terrace of its companion, the 4th. It is only 2½ feet thick at the points where it has been best exposed, and though probably larger in some localities, is not of such size or quality as to warrant its admission into our present careful estimate of productive quantity.

All of these coals lie between beds of the conglomerate rock, which form the main mass and crest of the Shamokin Mountain, and the interior of Coal Run Ridge, and, indeed, the general base of the whole coal-formation. In the region of Zerbe's Gap, near Trevorton, this division of the Coal-measures exposes four of the five coals here described, in perhaps their maximum dimensions, for they are there from 6 to 11 feet in thickness throughout a distance of several miles. The same four beds appear to be squeezed, at Shamokin Gap, by the mechanical pressure which attended the uplifting of the strata ; but E. of that probably somewhat dislocated portion of the mountain, where the excavating waters made their breach, these coals resume their regular or natural size, approximating to that exhibited in the more W. tracts of the basin.

The small fifth seam of the present enumeration appears to be an additional coal, which enters the conglomerate group E. of Shamokin Gap.

Assigning to them their truly available thicknesses, we find them to contain the following quantities of coal per acre :—

The 2d Coal of the series, with 6 feet thickness of good coal, will yield	10,000	tons per acre.
The 3d Coal, computed at 7 feet of good coal, will afford, say .	11,500	,,
The 4th Coal, counting it at 4½ feet, ...	7,500	,,

Making a total product of 29,000 tons per acre from the three seams.

Calculating from these data and their average areas within the basin, I find their total amount in coal to be equivalent to more than 42,000,000 of tons.

The whole of this vast quantity is not, however, to be considered as available for profitable mining. Though no portions of these beds descend to a depth which is not economically accessible even at the present day, yet a certain amount of their coal will inevitably be irreclaimable from the presence of irregular local undulations in the strata squeezing and nipping out the coal, or rendering it unfit for the market. All experience teaches that, after adding to this source of waste that which attaches to the present imperfect method of coal mining, by which a portion, more or less considerable, of otherwise good coal is left in the mines, or destroyed for use, a reduction of not less than 33 per cent will arise on the total quantity of good fuel in every such constructed coal-field. The basin before us promises to present but few faults, and as large a proportion of sound coal as the soundest basins of the anthracite region ; yet some bruised coal must occur where the strata dip as steeply as 45°, which is about their highest inclination on the flanks of the valley.

We come next to the set of coals immediately above the conglomerate series. These, if we divide the whole formation, as here developed, arbitrarily into three parts, form our second group, for which I propose the main conglomerate mass as the lower limit, and an overlying thinner conglomerate of small pebbles as the upper. The part of the coal strata between these two horizons includes, in the district before us, as many as eight separate beds of coal, four of which are usually of large dimensions, and two others generally of such size as to admit of economical mining. The outcrop or rise to the surface on the N. side of the basin is at the inner or S. foot of the steep slope or upper part of the Shamokin Mountain ; that is to say, at the upper limit of the long-inclined plane which extends from the bed of the valley to the first abrupt acclivity of the ridge. The place of each is marked by a separate and discernible, though, to an unpractised eye, not an obvious depression in the ground.

Dipping thence under the bed of the valley of Coal Run, they reascend on its S. side, and take their places on or in the N. flank of Coal Run Ridge. These coals do not appear above the water-level immediately at the gap near the W. end of Coal Run Ridge, inasmuch as the little conglomerate which surmounts them forms the interior stratum of the anticlinal arch at that place ; but E. they rise successively, and lap themselves over the axis of the mountain without emerging to the surface, while still further in the same direction they come forth to the day one after the other on the very crest, and there each parts into two outcrops, one to take its appropriate terrace high on the S. flank, the other a similar bench on the N. These middle large coals thus emerge on the summit of the mountain between Section No. 2 and Section No. 5, a space of about 3½ miles, throughout which they are all accessible, and have high working breasts.

They can be easily entered, especially on the N. side of Coal Run Ridge, by a short tunnel penetrating Southward low on the slope of the hill ; and when opened in that way, will each present a very long and increasing breast of coal, dipping at not more than an average inclination of 45° Northward into the Coal Run Basin ; or they may be very successfully commanded by the ordinary mode of slope-working, with stationary power at their outcrops on either side of the valley. Their distance below the surface, even in the centre of the basin, is not great. I question if it exceeds 400 feet in favourable spots. Their position at so moderate a depth, and their gradual dip from both sides of the valley to the centre, and also longitudinally for several miles towards the outlet of the valley, are features which strongly suggest the expediency of mining these beds of coal by a vertical shaft in the manner of the larger European collieries. The proper situation for a pit intended as an outlet to this middle series of coals, would be somewhere in the middle of Coal Run Valley, a mile or more to the Eastward of the gap, where their Eastward rise brings them to an easily-penetrated depth beneath the surface. Such a pit would not perforate any beds of resisting conglomerate, but would pass through soft shales, and the readily-drilled sandstones separating the coals.

I know of no spot in all the anthracite fields of Pennsylvania where a colliery on a colossal scale, upon this only efficient plan for a large and concentrated mining enterprise, could be more economically erected. A single pit of altogether manageable depth could be made to command and drain each concentric basin of three or four large coal-seams, from their lowest points upwards to their outcrops on *both sides* of the valley, and Eastward for 3 or 4 miles to the running-out lengthwise of each of their superposed troughs. This desirable method of winning the coal on the few large estates which offer the requisite facilities in the geological position of their coal-beds, is only to be undertaken by such as are willing to invest a fair amount of capital at the outset; but if judiciously organised, must prove, I am very confident, by far the least precarious, most easily conducted, and most permanently profitable of any known methods of mining adaptable to our coal-fields.

The lowest coal of this middle group, the *6th Coal* of our present enumeration, called Coal No. V. in the Trevorton portion of the general basin, has its outcrop in the Coal Run Basin at the foot of the first steep declivity of Shamokin Mountain, and lies high in the interior of Coal Run Ridge, on the very crest of which it rises out to the day in the neighbourhood of the central turnpike. It follows the Coal Run Basin to its E. extremity one mile at least E. of the turnpike. It occupies, therefore, an area of considerably more than 2½ square miles, or 1600 acres. Its average thickness is between 10 and 12 feet. On the slope of Shamokin Mountain, one mile E. of Coal Run Gap, it measures 11 feet, and contains less than 1 foot of slate and impure coal. The rest of the bed is excellent coal. On the summit of Coal Run Ridge, one or two miles further E., its size is about 10 feet; and one mile E. of Mount Carmel, the same coal has a thickness of 12 feet, and is very pure. I am therefore perfectly within bounds in assigning to this seam 9 feet of marketable coal, or 15,000 tons per acre for all that part of the basin which it underlies.

The *8th Coal* of the formation, though containing about 6 feet of coal at Shamokin Gap, where it is mined, has been less thoroughly explored than the other large masses, and I hesitate to assume it as yielding generally 6 feet of merchantable fuel. There can be no doubt, however, that its average product will exceed 4½ feet, or 7500 tons per acre.

The *9th Coal* of the formation in the Coal Run field, the Twin Coal of the Trevorton end of the region, is here, as very generally it is elsewhere, an admirably pure coal, and of large dimensions and great persistency of quality and features. In the locality now under review it is properly two coals, separated by a stratum of sandstone or sandy shale of from 15 to 17 feet in thickness. The lower bed has at Coal Run Basin the size of 9 feet, and contains 8 feet of excellent fuel; the upper is 4 feet thick, and may be relied on for a 3-feet thickness of good coal, giving the Twin mass 11 feet of available material; but I am disposed to rely only on the large bed, whose contents are equal to more than 13,000 tons per acre. The dimensions here cited are the smallest under which this bed has been found. Developments made in some places, especially in the basin S. of Coal Run Ridge, and in that S. of Red Ridge, exhibit a coal identical in all probability with this one, but materially thicker. The bed referred to has been opened on the McCall Lands, one mile E. of Mount Carmel, making a display of 22 feet of material between the roof and floor, with only 7 inches of slate in it, and 8 inches of inferior or bone coal. It there contains more than 20 feet of excellent anthracite.

I refrain from presenting at the present time any estimate of the fourth main coal of the middle group, as this seam has not been yet sufficiently identified and traced to furnish the elements of an accurate and safe calculation. Though in many localities a stratum of noble dimensions, it is somewhat inconstant in size, and is apt to subdivide itself by including slate and other materials.

Rejecting also for the present the four remaining smaller beds of this series as not susceptible, until better explored, of very precise determination as to their amounts of available coal, I shall pass on to consider the chief seams of the higher or third division of the formation, or that part which overlies the so-called Little conglomerate.

In this group we have established, as already indicated, the existence, and traced with more or less accuracy, the outcrops of five coal-seams of 3 feet and more in thickness, and there are reasons for admitting one or two other beds of workable dimensions into the series. The coals now before us take their place for the chief part in the valley. In Coal Run Basin, the upper seams spread themselves with gentle dips from both sides under the broad and nearly flat bed of the Western portion of the valley. These are chiefly, if not all of them, Red-Ash coals. The lower beds of the group ascend the flanks of the anticlinal ridges where these are low or subsiding, and there arch themselves over their crests in bold and regular anticlinal curves. Such is the attitude held by the two largest and lowest of the series at the three several anticlinal notches—that of Coal Run Gap in Coal Run Ridge, that of Shamokin Creek in Red Ridge, and that of the same stream in Jamie's Ridge. At each of these points these two important coals present themselves on the two opposite flanks of the ridges, offering the easiest conceivable access to fair and even ample breasts of coal above the water-level. As the higher beds are of inferior size, and of more restricted areas and less lifted position, I shall confine myself, in the present description and estimate, to the two lower ones before us.

The first in ascending order, resting at an interval of seldom more than 20 feet above the little conglomerate, which divides this inferior from the middle group of coals, is an admirably pure and clear coal, of very ample dimensions. It is about the 13th bed of noticeable size in the coal-formation. In the W. end of the Shamokin Basin, where it is the highest coal there preserved, it frequently exhibits a total thickness of 6 or 7 feet, but it is there usually divided by a layer of sandy shale or sandstone, a foot or two in size. Eastward from Shamokin, the proportion of good coal in it seems to augment, for at Coal Run Gap it contains, in a thickness of 7 feet, more than 6 feet of fuel of a quality unsurpassed, and in the middle and Eastern districts of the Coal Run and North Shamokin basins a considerably greater amount. In the anticlinals of Red Ridge and Jamie's Ridge, at the passage of the North Branch of Shamokin Creek through them (see the wood engraving, fig. 241), this excellent bed attains the size of 14 feet, and, holding about this magnitude, it follows both flanks of each of these ridges, and gradually rises to the Eastward in the two basins which these ridges and Coal Run Ridge include between them. Of this coal a very ample proportion holds a position above the water-levels of the gaps already mentioned as intersecting it. It can there be entered endwise, and mined Eastward and Westward on both the N. and the S. dips of the anticlinals, making, in fact, at each of these three natural inlets to it, four separate collieries of more than the average scale of productiveness, susceptible of ready expansion in future years by the method of underground slope-pits. I will not at present pretend to offer a calculation of the total quantity of good coal in this valuable seam, nor even of the large quantity accessible above the lowest water-levels at the bases of the hills into which it rises, but I am able to produce a pretty safe approximate estimate for the Coal Run Basin and the W. end of Coal Run Ridge. The extensive researches undertaken in quest of this coal, and its companion seam above it, by lines of shafting across the Western end of the basin, and over the flanks and crest of the ridge, permit me to estimate with confidence its minimum ascertained thickness of pure coal at about 6 feet in Coal Run Basin and Ridge. We have here not less than Ten Millions of tons of excellent anthracite.

The next and last coal to which I shall specially refer, the 14th Coal of our general series, overlies that above described at an interval of about 50 feet. Like its lower companion, it is a beautifully pure mass of fuel, but its prevailing thickness is less than that of its mate. At the gap in Coal Run Ridge it measures in all 6 feet, and may be estimated as yielding throughout the region 4½ feet of good coal. It admits of the same facilities in mining which belong to the larger coal near it, rising in extensive breasts above the water-levels of the country. Occupying about the same area, say, in the basin and ridge of Coal Run alone 1000 acres, of which an extensive portion can be reached without a shaft, or slopes, or even a tunnel, and indicating an average product of certainly 7500 tons per acre, it promises to contain not less than 7,500,000 of good fuel, and to afford by mining a nett yield of fully 5,000,000 of tons from the one district here designated. These two coals, thus defined, seem to constitute the uppermost of the main workable beds of the true White-Ash class in this part of the Shamokin coal-region. Above them in the series we soon enter a group of beds, which furnish pinkish-grey and red ashes. Two or three of these occur in the middle of the Coal Run Basin, and are to be met with in the other deeper tracts of the coal-field; but as their limits have not yet been traced with the requisite precision, I refrain from attempting a description of them. While the coals here described are as easily ignited as the chief part of the free-burning Red-Ash class are known to be, they possess the very important superiority for the leading uses to which anthracite is applied as a fuel, of producing a comparatively infusible white ash, thus exempting the furnace-grate from the large share of clinker or stony slag which is so mischievous in a strong fire of Red-Ash coal. These coals ignite readily, and consume very rapidly under a sufficient draft. This adapts them well for all purposes of speed and power: while some of them are sufficiently firm to take any shape, and to bear the roughest handling, other beds are unprofitably soft or tender. They are, as already intimated, 3 feet and more in thickness.

Thus we learn that there are in all some seventeen or eighteen coal-beds of notable dimensions in the coal-field E. of Shamokin, and that eleven or twelve of this number are of such magnitude and average soundness as to warrant confident anticipations of their fitness for mining. Of these, four or five are of a bulk and excellence not generally met with.

CHAPTER II.

STRUCTURE AND CONTENTS OF THE COAL-FIELD BETWEEN SHAMOKIN GAP AND THE WESTERN EXTREMITY OF THE BASIN.

That portion of the coal-field which lies between Carbon Run and the crest of the Mahanoy Mountain having been already illustrated in detail, I proceed now to take up, in continuation of the central and Northern basins, the district which is occupied by Carbon Run. It extends from this stream to the crest of the Shamokin Mountain. Of this valuable portion of the coal-field extremely little is specifically known, in respect either to its structure or its coal, no portion of it, except that bordering on the Shamokin Creek, having been as yet explored by any systematically-organised surface-shafting, or by mining. Even its subordinate flexures, the tracing of which can only be effected through a well-conducted opening of its coal-beds, remain to be discovered and located. I must therefore content myself with a meagre and general description of all this tract. Passing the summit of the watershed which separates Carbon Run from Zerbe's Run, we enter upon ground which has been extensively and successfully explored, and from this point to the end of the basin, a distance of some 5 miles, a very satisfactory picture can be given of its interesting structure and its vast resources.

The N. half of the coal-field, or that which lies between Carbon Run and the summit of the Shamokin Mountain, is evidently traversed, like the district intersected by the Shamokin Creek, by several anticlinal flexures, the prolongations of those which are so conspicuous further E., and which are indicated on our main Section through the village of Shamokin. These undulations are not traceable in detail W. of the meridian of Shamokin Gap, as this district has not as yet received much development : but it is apparent that the second, fourth, and fifth anticlinals S. of Shamokin extend a considerable distance into it. It is obvious, however, that some of the half-dozen axes which pass into this side of the coal-field W. of the Shamokin Creek expire before they reach the sources of Carbon Run, where the structure of the basin is manifestly more simple. It would appear that these Northern undulations maintain an average direction very nearly parallel with the crest of the Shamokin Mountain ; they must therefore converge at a very acute angle upon the Mahanoy Mountain, as they pass the watershed of Carbon Run, precisely as we have already seen those S. of that stream run into this ridge. At the watershed which divides Carbon Run from Zerbe's Run, the general basin contains apparently only three anticlinal axes, some of the others having died away, or one or two of the more Southern ones having smoothed themselves out into the N. dips of the S. side of the basin. Passing the meridian of Zerbe's Gap, we discover that the most Southern of these three has thus disappeared on the N. slope of the Mahanoy Mountain, so that the narrow end of the basin, or that watered by the West Branch of Zerbe's Run, presents but two undulations, until at last, towards the Western source of that stream, the more Southern of these two remaining ones flattens away in a similar manner as it draws near the Southern Mountain, leaving the N. axis alone to approach the head of the basin, which it does not reach. It would thus appear that every one of the anticlinals of the Shamokin Coal-field, some fourteen in number at the least, where Buck Run and the Shamokin intersect the valley, either runs into the N. flank of the Mahanoy Mountain, or dies away within the basin while converging towards it.

The coal-seams N. of Carbon Run have nowhere been fairly shafted on or opened for mining, except at a locality between that stream and Furnace Run, a little W. of Shamokin Gap ; there the Coal-measures have been carefully explored in the Sub-basins *a*, *b*, and *c* of Basin 9 ; and it has been ascertained that the top bed identified is the sixteenth in the ascending series, or the third above Rosser's Vein, which appears to be the thirteenth. Several of these coal-seams are of ample thickness for mining, and some of them, notwithstanding a prevailing steepness in the dips, give promise of being profitable.

COAL-BEDS ON THE SCOTT AND HUNTER TRACTS SOUTH OF CARBON RUN.

These lands are situated W. of Mowray's Run on the N. slope of the Mahanoy Mountain, and are traversed by the anticlinal No. 7, and the subordinate flexures N. and S. of it. A correct notion of the general condition of the coals which they contain, their undulations, and rapid alternations of dip, may be had from an inspection of the two printed Sections illustrating the corresponding part of the coal-field on Gerhart's Run and on Buck Run. (See Section from Shamokin to Locust Mountain.) This portion of the S. side of the coal-field (and the remark applies to the whole belt as far W. as the source of Carbon Run) is composed simply of six or seven slender parallel troughs of the coal-strata, embracing a greater and increasing depth of the formation from the top of the mountain down its long flank to the bed of Carbon Run, each individual trough rising W., and gradually flattening or losing itself in the prevailing N. dip of the strata towards the summit. West of Mowray's Run, the total ascent from the bed of Carbon Run to the summit of the mountain, which is a distance of nearly one mile, is about 790 feet.

The coal-seams experimentally opened by shaftings in this neighbourhood, at the date of our observations (1854), were eleven in number, and three of these are of important thickness. The thinnest of these workable beds, No. V. of the general series of the Shamokin Basin, is from 4½ to 6 feet thick when regular; the next large bed No. VIII. contains, when regular, about 9 feet of good coal; and the third important seam, or Coal IX. of the series—the Rennie Coal of Zerbe's Gap—is not less than 18 feet thick.

The coals of this part of the coal-field belong to the class of soft White-Ash anthracite, intermediate in specific gravity and hardness between the denser and firmer coals E. of Shamokin and the free-burning semi-anthracites of the district of Zerbe's Gap. Like these latter Western coals, they are intersected by numerous fine planes of cleavage, giving a tendency to subdivide while kindling. The coal of this district contains on an average from 5 to 7 per cent of volatile matter, 3 or 4 per cent being inflammable gaseous matter, contributing to the rapid kindling of the fuel.

WESTERN END OF THE BASIN, OR THAT WATERED BY THE EAST AND WEST BRANCHES OF ZERBE'S RUN.

This terminal portion of the basin is a little more than 4 miles long at the source of the East Branch of Zerbe's Run; its breadth, from the crest of the Locust or Mahanoy Mountain to that of the Shamokin Mountain, is nearly 1¾ miles, but the trough contracts very regularly to its W. extremity by the converging of the two mountain-barriers. Its whole form is slightly curved, even the S. barrier bending gently Southward in its progress Westward; the N. one deflecting in the same direction more conspicuously. The Eastern widest half of the district, watered by the East Branch of Zerbe's Run, has its deepest depression on the immediate valley of that stream towards its N. side at the foot of the Shamokin Mountain, and not in the middle of the basin, which is a rather broad and elevated table-land, presenting a good height of breast in its coal-seams above the water-level of Zerbe's Gap. This elevation of the centre of the valley is due chiefly to the influence of the central anticlinal flexure of the basin. West of the meridian of the gap the surface of the valley is more symmetrically trough-shaped, a feature which it owes to the flattening away of the undulations in its interior, and the greater predominant influence, therefore, of the synclinal dips from its two borders.

The general structure of this part of the Shamokin Basin is very simple. The strata of the summit and N. slope of the Locust Mountain dip Northward with an inclination which increases as they range towards the Westward, from a slope of 60° opposite the watershed E. of Zerbe's Run to one of 70°, or even 75°, at the W. extremity of the basin. Those of the Shamokin Mountain—the N. border—dip S. also at a steep angle; but, contrary to the inclinations in the S. barrier, they flatten off more and more as they approach the W. end of the coal-field, being at the watershed of the valley as highly inclined as 60°, subsiding to 50° in crossing Zerbe's Gap, and thence, in their progress Westward, sinking steadily to 40°, 30°, and probably 20°, until, at the elevated end of the valley, all the strata swing round with about this dip, and join their steeply-inclined counterparts of the S. side of the trough. This W. end of the basin is drained centrally by the West Branch of Zerbe's Run, from the lower part of the valley of which, or, better still, from the main stream itself at a still lower level, a tunnel might be cut Southward intersecting all the coals of the central and S. side of the coal-field. The deep cleft in the Shamokin Mountain, named Zerbe's Gap, offers an admirably convenient inlet to the coal of all the N. border of the basin, giving immediate and cheap access to the entire suite of the coal-beds which there outcrop at a steep angle in both slopes of the notch, where some of them are now actively mined, being entered endwise by drifts and even counter-levels above the water-level of the gap. From this point much of the coal above this low level can be extracted from the slope of the Shamokin Mountain, and indeed no small portion of the whole field of coal above the same level, lying W. of the notch, can be thus ultimately reached without the aid of either tunnel or slope; for as the levels or gangways penetrate further W., the bottom of the whole basin rises to reach them, and a greater and greater proportion of the basin of each coal-bed presents itself between the water-level and its outcrop on the mountain, the length of each upper breast being much increased also from the twofold circumstance of the progressive flattening of the dip and the actual rise in the outcrop of each bed.

Coal-seams in the Zerbe's Run, or Trevorton District of the Shamokin Coal-field.—This portion of the Shamokin Coal-field having been carefully and systematically explored through the enterprise of the parties owning the land, who placed at the disposal of the Author workmen for the development of its coal-beds, a more than usually full account can be given of the Coal-measures and valuable seams of fuel which they include. Calling the attention of the reader to the two Sections of the coal-field, representing the strata at Eyster Gap or Zerbe's Gap, near Trevorton, I proceed to offer a concise account of the Coal-measures and their contents.

The Zerbe's Run and Shamokin coal-lands lie in the W. portion of the great Shamokin coal-basin, having their W. boundary within about 3 miles of its termination, in a line which passes nearly N. and S. through the deep water-gap of Zerbe's Run. This coal-field therefore adjoins that of the Mahanoy and Shamokin Improvement Company, and shares with it the privilege of the natural outlet and deep water-level conferred by this mountain-notch on this part of the basin. It includes the whole breadth of the coal-valley, from the summit of the Big or Shamokin Mountain to that of the Mahanoy Mountain, the lands extending, indeed, into the outside Red Shale valleys on either side. In an E. and W. direction the property has a length of about 1½ miles, and its average breadth is just 2 miles. The part which is embraced in the coal-basin possesses an average breadth of 1½ miles, its length being also 1½ miles. Another estate, that of the Mahanoy and Shamokin Improvement Company, embraces the entire breadth of the Western end of the Shamokin Coal-basin, from the Water Gap of Zerbe's Run, to the junction of the Big and Mahanoy mountains at the termination of the coal-basin. These two estates occupy about 4 miles of the coal-field.

The geological structure of the coal-field is regular and simple, while it is such as to place the coal in positions highly advantageous for economical mining operations. On the N. and S. sides, the strata containing the coal-beds ascend to the crests of the respective mountains. Dipping inward as respects the coal-valley at angles varying from 45° to 60°, the successive sheets of coal penetrate in a leaning attitude the entire depth of each of these bounding ridges. But instead of meeting under the middle of the valley in a simple trough or single basin, the strata, soon after passing below the foot of each mountain, reascend to form an arch or convex curve in the central belt. Each layer of rock and bed of coal, therefore, if traced in its course from one mountain to the other across the basin, exhibits a broad undulation, consisting of two deep synclinal flexures and a central anticlinal one, or two lateral troughs and an intermediate arch. The arching of the strata in the middle of the valley, causes this part of it to be occupied by a broad and rather elevated ridge. Between the N. base of this ridge, and the S. foot of the Big Mountain is the synclinal valley of Zerbe's Run, while between its S. slope and the N. foot of the Mahanoy, or South-bounding mountain, the other synclinal zone has not the surface of a valley, but is an elevated flat table-land connecting the base of the mountain with the brow of the ridge. The double flexure of the strata, and the configuration of the surface here described, are features admirably suited for affording a cheap and ready access to a very large amount of coal. It admits, in fact, of a double set of collieries, where otherwise, had it the structure of a simple trough, the basin could contain but a single series. The same bed of coal presents four breasts for mining, in place of two, and fills the middle of the coal-valley with a number of easily-penetrated coal-seams ascending above the water-levels, where, under the other feature, these would have been buried several hundred feet beneath the bed of the valley.

The deep position of the valley of Zerbe's Run, at the inner or S. foot of the Northern Mountain of the basin, and the very low relative level of the mountain-notch, the natural outlet of this valley, give us control of an enormous amount of coal above the water-levels of the surface. The vertical height of the mountain-crests on both sides of the basin, in the vicinity of Zerbe's Gap, is about 450 feet, but the elevation increases as we recede. The Central Anthracite Ridge, and the table-land to the S. of it, have an elevation above the water-level of Zerbe's Run of from 200 to 300 feet. The mountains will therefore afford breasts of coal averaging from 600 to 700 feet in height, and the central tracts of the valley, breasts varying with the dip from 300 to 700 feet.

The coal-field thus defined contains an uncommonly large amount of coal per acre ; indeed, in this respect it rivals the richest in the whole compass of the anthracite country. It derives this extraordinary wealth from a combination of unusual and very favourable features in the coal-formation. The most important and influential of these is, the presence of large and valuable beds of very pure coal in the great underlying conglomerate, a part of the formation which, in nearly every other neighbourhood, contains either no coal at all, or only one or two beds of inferior quality and dimensions. In the Wiconisco Basin, and also in the Dauphin Coal-field, the conglomerate embraces, as we have already seen, one or two beds of coal of a profitable size and of good quality ; but in the district before us, this stratum includes as many as five separate seams of the best free-burning anthracite, four of them of large dimensions, and of unusual excellence in the quality of their fuel. It would appear to be a general fact in the relative distribution of the coal within the strata, that the lower stratum (the conglomerate) becomes a productive coal-bearing member of the formation only when we approach the W. terminations of the two great S. basins, and this not in an equal degree as regards these basins, but in a ratio of much more rapid increase in the more Northern of the two, the great Shamokin Valley. The direction of maximum development of the lower coals has therefore been nearly due Westward, or into the W. end of the Shamokin Basin, from the region of the Schuylkill, and not strictly along the course of the Southern or Pottsville Basin.

Owing to this unusual expansion of the coal-seams of the lower division of the formation in the W. part of the Shamokin Basin, the quantity of coal is greater for the thickness of the strata embracing it, than in any other quarter of the anthracite region. The actual depth, or thickness of the whole formation, including its inferior member—the conglomerate—at Zerbe's Gap, does not exceed 1000 feet. This mass of strata consists of two nearly equal divisions: the lower, comprising a little more than 500 feet, consists of five separate beds of massive silicious conglomerate and coarse sandstone, alternating with five deposits of argillaceous shale and slate, the conglomerate constituting about one-half of the whole thickness. Each of the argillaceous or slaty deposits contains a thick bed of coal. The upper division consists mainly of bluish shales and dark carbonaceous laminated coal-slates, and includes five separate and recognisable beds of fine-grained compact silicious sandstone, one of which, the fourth in ascending series, is surmounted by a thin pebbly rock or conglomerate, easily distinguishable from the conglomerates of the lower series by the smaller size of its fragments. In this upper series there occur on Zerbe's Run eight separate beds of pure coal, five of which, and occasionally a sixth, are amply large enough for profitable mining, three of them being of rather extraordinary size. Thus in the whole thickness of about 1000 feet of coal-rocks, thirteen beds of coal present themselves, nine of which are everywhere large enough and pure enough to be advantageously wrought.

DESCRIPTION OF THE INDIVIDUAL COAL-SEAMS IN THE ASCENDING ORDER.

Coal Zero.—The lowest coal, called *Zero*, from its underlying the No. 1 of a previously-established enumeration, occurs within a short distance of the upper limit of the Umbral Red Shale; its total thickness is about 5½ feet, but it contains near the middle a layer of slate 18 inches thick, which divides it into two benches of coal, an upper one 2½ feet, and a lower one 1½ feet thick. It has been proved and drifted on, but not hitherto mined in a permanent manner. It is illustrated by the accompanying cut.

Fig. 245. — Lowest Coal, Zerbe's Gap.

Coal I.—This, the second bed of the conglomerate series, lies within 100 feet of the base of the formation. It passes under the entire basin, and has its N. outcrop usually on the first bench or platform outside, or N. of the crest of the North Mountain, and its S. outcrop generally on the second bench, outside or S. of the summit of the South Mountain. It has been already mined to some extent in the end of the North Mountain, at the gap, and there displays a thickness of 12½ feet of excellent free-burning and flaming anthracite. Of the 12½ feet of coal, about 11 feet are of superior quality, adapted to the market. Further E., about half a mile, this coal shows a thickness of 8 feet in a superficial shaft on the mountain. On the S. side of the basin it has a thickness, where it has been opened, of 11 feet. We may safely

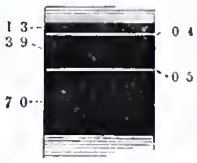


Fig. 246. – Coal I., Zerbe's Gap, Treverton.

estimate it to possess 9 feet of available coal, or to contain *three tons* to each square yard of surface.

Coal II.—This coal overlies the second layer of conglomerate, and is higher in the series than Coal I. by about 150 feet of strata. Its outcrop is usually indicated by a distinct bench on each mountain, and its horizontal distance from the outcrop of Coal I. is, on an average, about 250 feet. The line of its outcrop along the Northern Mountain is immediately to the S. of the highest crest, which is here formed by its underlying conglomerate. On the South-bounding ridge it comes to the day sometimes on the first bench, sometimes on the second S. of the main crest of the mountain. The average thickness of this coal would appear to be about 8 feet, and we are safe in computing the quantity of good fuel in it at 6 feet, or 2 tons per square yard of surface.

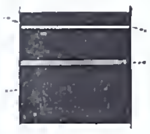


Fig. 247. — Coal II., W. side of Zerbe's Gap.

Coal III.—Separated from Coal II. by about 120 feet of strata, and distant from it usually about 200 feet, at a dip of 45°, Coal III. is easily traced along the next parallel interior bench or terrace. On the S. barrier of the basin this bench is conspicuously marked, and throughout the greater part of its course from W. to E., it lies immediately N. of the crest outcrop of conglomerate, except next the E. end, where it changes to the S. or outside base of the crest ledge. Conglomerate No. 3, which underlies it, and also conglomerate No. 4, above it, are thinner and less massive rocks than conglomerate No. 2, and therefore the terraces defining Coals III. and IV. are, for the most part, more obscure than those of either Coals II. or I. Along the S. side of the crest of the N. barrier, the want of prominence in the third and fourth conglomerates causes the outcrops of Coals III. and IV. to be only very vaguely indicated on the surface. A knowledge of their distances from the other better-defined outcrops is here, therefore, very important.

West of Zerbe's Gap, Coal III. has, on the North Mountain, an average thickness of about 10 feet; and E. of the gap, on the same line of outcrops, the shafting shows it to contain about 8 feet of coal, of which 7 feet are of excellent quality. Making a fair abatement for accidents and inevitable waste, this coal will yield, I think, at least 6 feet of marketable fuel.

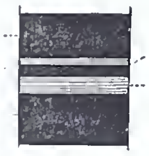


Fig. 248.—Coal III., near Zerbe's Gap, Trevorton.

Coal IV.—Divided from Coal III. by the thin conglomerate No. 4, this coal occupies for the most part the same broad bench with it; they are separated by about 70 or 80 feet of strata, and on the N. side of the basin are in some places yet nearer together. The horizontal space between their outcrops, therefore, rarely exceeds 100 feet. Coal IV. is generally rather thinner than either of the other three conglomerate coals. We shall be very safe, however, in assigning to it a productive thickness of 6 feet.

Coal V.—This valuable and large bed, the lowest of the sandstone series, has its outcrop invariably at the base of a long slope formed by the upper or fifth belt of conglomerate, on a terrace or bench somewhat lower on the inner flank of the mountain than those above described. It overlies the conglomerate from 20 to 25 feet, the interposed rock being a soft blue argillaceous shale. Above it is a thickness generally of 60 feet of similar shale and dark carbonaceous slate. The edge or brow of the terrace, along which this coal appears, is formed by a fine-grained compact flaggy sandstone, usually from 16 to 20 feet in thickness; the terrace, thus supported, exceeding 100 feet in width.

This coal-bed has an average thickness in this district of about 15 feet, but in some places its outcrop shows it to contain even 17 feet of good coal. It is exceedingly pure in quality. Underlying the entire basin, between its N. and S. outcrops, which are high on the flanks of the bounding mountains, it constitutes of itself, from its great thickness, a coal-field of enormous capacity. It will be perfectly prudent to estimate it as yielding a thickness of 10 feet of coal fit for market, and as holding in the North Mountain, where it is at present most accessible, a breast above water-level of at least 500 feet.

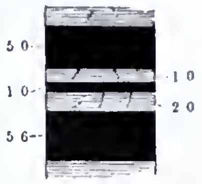


Fig. 249.—Coal V., Zerbe's Gap, Trevorton.

Coal VI. is a thin coal, pure in quality, but seldom met with of a greater thickness than 18 inches, and therefore not at present of any commercial value. It lies about 20 feet above the first sandstone.

Coal VII.—This is a coal which varies in size from 5 to 7 feet. Its available dimensions may be estimated at 4½ feet, and its capacity, therefore, at one and a half tons to the square yard of surface. I shall assign to it, however, 1 ton. It has its extreme outcrops high on the sides of the coal valley, usually about 100 feet from the outcrops of Coal V., on the gentle slope below the terrace connected with that coal. This is the lowest coal-bed of the whole series which reaches the day in the anticlinal tract of the middle of the basin. It is high enough to be brought to the surface over the centre of the arch or saddle, where the first tributary of the Eastern Branch of Zerbe's Run passes through the central ridge by a somewhat deep transverse valley or ravine. At this point the coal has been opened precisely at the saddle or anticlinal axis, at an elevation of about 50 feet above the bed of the ravine. If at some future time it were deemed desirable to extract the coal from this bed in this central belt, the spot here designated is a very favourable one for the construction of slope-workings, by which it might be wrought on both the N. and S. dips of the saddle.

A perpendicular shaft in the valley of Zerbe's Run, at the foot of the North Mountain, only a few hundred feet in depth, would, by penetrating to the bottom of the N. synclinal trough embraced between the mountain and the middle ridge, gain ready access not merely to all the coal of this bed under the water-level, but to that far larger amount which the basin there contains in the five great underlying seams previously described.

Coal VIII.—Immediately upon Coal VII. is the second sandstone, usually about 15 feet thick. It forms, in most localities, the margin of the sloping bench which holds the outcrop of Coal VII., and gives rise to a slope of the surface, about midway upon the flank of which we are entitled to look for the outcrop of the large and excellent Coal VIII. This coal-seam, which is remarkable throughout the district for its superiority, and the great persistency of its features, is a double or twin bed, being divided in the centre by a layer of soft argillaceous shale, often a pure fireclay, which, though seldom a foot in thickness, holds its place and size, with little variation, over an extent of some miles. The position of the Northern and Southern outcrops of this coal is about midway on the long gentle ascent of each mountain which leads up to the terrace of Coal V., at the foot of the first steep acclivity, or that of the upper conglomerate. Its average angle of dip on the two sides of the basin is about 45° or 50°. Passing under the two lateral basins, it rises in the anticlinal arch of the central broad ridge, and has here been opened immediately on the top of the saddle W. of a transverse ravine, a mile E. of Zerbe's Gap. Farther W. it is overarched by higher strata, but throughout the whole length of the district of the East Branch of Zerbe's

Run, this coal is elevated nearly to the surface, along the centre of the anticlinal belt, and presents, especially in the N. side of the ridge, a valuable and tall breast of coal with a moderately gentle N. dip.

This bed has an average thickness of good coal of at least 14 or 15 feet. On the North Mountain it displays, in a well-opened shaft, a total thickness of 22 feet. We are within bounds, therefore, in assigning to it, after deduction, a product of 4 tons per square yard. In the North Mountain E. of the gap, its breast above the water-level is not less than 600 feet, in consequence of a flattening of the dip due to an anticlinal fold which lies near its outcrop on the slope of the ridge.

Coal IX.—This is generally the thickest coal-bed of the series. When in fullest development, as in the vicinity of Rennie's Cottage, it consists of two separate layers, the higher being from 15 to 16 feet thick, and the lower about 4 feet. In many localities, both E. and W. of the Gap, the lower bench is either absent or very thin. The coal, a soft free-burning and flaming anthracite, is, for so large a bed, singularly pure, being free from both sulphur and slate. At a very moderate estimate, this coal will yield 4 tons to each square yard of surface. In the North Mountain, its line of outcrop is low on the flank of the ridge, and the breast of coal there, above water-level, does not probably exceed 200 feet. In the central anticlinal ridge, where its outcrop follows the N. brow of the hill for the whole length of the stream, at an average vertical height of 200 feet, and a dip which rarely exceeds 30°, the extent of the breast is at least twice as great.

Between Coal VIII. and this Coal IX. there is a coarse grey sandstone, No. 3, the outcrop of which frequently forms, for the two coal-beds, two independent benches, or else two separate slopes. Overlying Coal IX. is a coarse, gritty, whitish sandstone, No. 4, divided from it by about 110 feet of soft slate.

Coal X.—Above the large bed, Coal IX., at an interval of about 30 feet, is the thin Coal No. X. It is of no economical importance, since it rarely contains 2 feet of good coal. The roof or top slate of this seam is unusually rich in the flattened stems of several species of *Sigillaria*, one of the chief coal-producing plants. They are thoroughly compressed, and form a complete matting. At one spot near the gap, the strata having a perpendicular dip, this top slate is exposed to the open day at a superficial trench excavated in the outcrop of the coal-bed. (See the Sketch at the end of this Chapter.)

Coal XI. overlies Coal IX. at an interval of from 90 to 100 feet. This coal is occasionally 3 feet thick, and is then of available size, and may be estimated at 1 ton of good coal for each square yard of surface; but it cannot at present be included in any account of the resources of the coal district.

Coal XII.—The sandstone, No. 4, is surmounted by a fine-grained conglomerate, which everywhere along the summit of the central ridge exposes two well-marked lines of outcrop, serving as excellent external guides to the position of the adjacent coals. Overlying this conglomerate is a thin body of slate, and then a thin sandstone, and at a short interval above this sandstone lies the upper coal of the whole series, Coal XII. of our enumeration. This bed is generally double, its lower layer being about 5 feet thick, separated from the upper, which is from 1 to 2 feet thick, by 2 feet of sandstone and slate. It may be safely estimated to afford 1 ton of good coal to each square yard of surface. Its outcrop on the North Mountain is too low above the water-level to make it eligible to mine it there at this time, but in the N. flank of the central ridge it has a breast of considerable height, probably not less, on an average, than 100 yards.

If at any time it were thought desirable to enlarge the productive capacity of the district by an additional series of collieries, the whole central belt of the basin, and its entire S. side, may be promptly and effectually laid open to the same low water-level by the construction of a single transverse *tunnel,* entering the central anticlinal ridge opposite the gap, and penetrating Southward to the lowest coal-beds of the S. barrier. This tunnel would, near its mouth, procure access to tall breasts of coal on the several large North-dipping beds of the anticlinal ridge; further in, it would intersect the same coal dipping Southward, and further still, it would cut deep across the broad basin at the foot of the South Mountain, and terminate beyond in the coals of the conglomerate series, at so low a relative level as to lay open working breasts of the entire sloping height of the ridge. By this tunnel, which would be equally available for the development of the central and Southern tracts of both the E. and W. divisions of the district, all the coal anywhere above water-level, even to the Eastern boundary of the valley of Zerbe's Run, would be procurable without machinery. As the tunnel would expose new and extensive breasts of thick coal at short intervals of its progress, its cost would be covered as it proceeded. If judiciously planned, such a work might, I feel confident, give outlet to at least 12,000,000 of tons of coal.

The researches undertaken permit us to calculate, with very considerable precision, the grand total of coal embraced within the limits of this coal-field. By the estimates already presented, the aggregate thickness of the coal truly available in the beds appears to be about 70 feet. But it is not of this full thickness under every part of the valley, since the higher seams—and among these occur the largest ones—do not spread across the basin to limits as wide as the lowest.

In all my estimates of the amount of available coal in each bed, compared with the total quantity contained between the roof and floor, I have been studious to exceed rather than to underrate the proportion of waste arising from the operations of mining, and from the more or less squeezed or crushed condition incident to the coal in all basins where the bounding dips of the strata are at all steep. Much attention has been devoted to the detection of the probable amount of this last-mentioned element of waste. In the Shamokin, and in every other anthracite coal-field, portions of certain coal-beds are necessarily faulty, and as usual the most disturbed part of the basin is its S. margin. Even there, however, the proportion of the crushed coal to the undisturbed, owing to the regularity of the dip, is less than belongs generally to the North-dipping belts of strata of the more Southern coal-fields. Throughout the N. side, and all the central tracts of the estate, the prevailing soundness of the coal is remarkable.

It is a highly favourable circumstance in the structure of this whole Western division of the Shamokin Basin, that its natural outlets, and therefore its deepest water-levels, and first available breasts of coal, are all on the *N. side,* and not, as in nearly every part of the Pottsville Basin and its branches, in the Southern Mountain barrier. By this condition of things, the most accessible part of the coal-field is at the same time the soundest, and all those great breasts of coal, which will call for the least preliminary outlay for development, are precisely those also which will call for least expense in mining, and involve to the collier the smallest delay and disappointment. Those persons who are at all familiar with the history of the mining enterprises of the Southern anthracite basin, will justly appreciate the value of this fortunate combination of low water-levels with a great range of regular South-dipping strata.

It is obvious, from the foregoing statements respecting the thicknesses of the several coals, and their high breasts above the existing water-levels, that the present productive capacity of this coal-field is unusually great. Its facilities for furnishing a large annual supply of good coal to the market, at a minimum of preliminary arrangements for mining, are indeed remarkable. Extensive collieries, working above the water-level, are already organised, from which, without any expensive erections, a large amount of coal can be annually sent to market over the Trevorton Railroad, now constructed to the Susquehanna.

In no part of the anthracite coal-region do all the conditions favourable to facility and cheapness of mining concur to a greater extent than in this basin.

Having now offered a general sketch of the structure and large resources of the coal-field of Trevorton or Zerbe's Gap, I shall submit a brief description of the coal itself.

Obeying the general law of gradation exhibited in the composition of the coal in all the great anthracite basins of Pennsylvania, that of the Shamokin Valley grows progressively softer and less compact, and more gaseous and free-burning, as we follow it toward its Western termination. Passing the meridian of the Shamokin Gap, the coal acquires a sensible quantity of the inflammable gas (carburetted hydrogen) characteristic of the bituminous and semi-bituminous class of coals, and the proportion of this ingredient seems rapidly to increase as we draw near to the extremity of the basin: it is therefore at its maximum in the terminating coal-field before us. It constitutes probably not more than eight or nine per cent by weight of the coal at Zerbe's Gap; yet small as is this amount of the volatile matter, it imparts to the fuel properties which, for an anthracite, are peculiar, and some of which are highly valuable. It seems to exist in the coal in the gaseous form, or if a portion of it is in a condition of liquid bitumen, it is in quantity too minute to cause the coal to soften and form coke. The coal is therefore to be regarded as an anthracite, but of modified properties. When a portion of the coal is freshly thrown upon an ignited fire, it begins very quickly to discharge its inflammable gas, which may be seen burning with its peculiar yellow flame, and causing by its ready combustibility the solid part of the coal itself to pass rapidly into full ignition. It is otherwise with the hard varieties of anthracite; these are destitute of any such *good kindling*, and are, moreover, slow to burn from their extreme compactness, so that when they are cast fresh and cold upon a fire, they check seriously the vigour of the combustion, and produce irregularity in the heat. The quality of being easily kindled confers on these free-burning semi-anthracites an especial fitness for generating steam. From the same property will arise an important economy in the consumption of the coal, as this can be kept ignited in small quantities, and in a state of low combustion; while the harder and less ignitable kinds, not burning at all but at a higher temperature, will either go out altogether, or produce a fire which, for many purposes, is wastefully active and intense.

Some of these free-burning coals of this Western Shamokin coal-field are liable to crumble or fall, to a certain degree, during the first stages of their combustion; though it is to be observed, that the coal hitherto submitted to experiment has been procured from near the outcrops of the beds, or where the mine has but little cover. Analogy tells us that the coal will be firmer on the fire when taken from a deeper source. I think, however, that this tendency to crumble when burning is partly inherent in the composition of the coal, and is in fact connected with the disengagement of the inflammable expansible gas before referred to, which, in assuming the volatile condition, swells and severs the coal by its minute mechanical fissures. The breaking up of the coarse lumps into smaller ones, while it greatly increases the total surface exposed to combustion, does not necessarily lessen the aggregate quantity of interstitial space for the passage of the air. There is just the same proportion of air-space in a cubic yard of *small shot* as in a cubic yard of cannon-balls. It is a fixed geometrical ratio. It must be acknowledged, however, that the soft coals demand additional force of blast.

The openness of the fire to the air is furthermore preserved by a valuable quality in the earthy residuum of these coals. The ash is white and apparently very silicious, and therefore extremely infusible. The flakes cohere only by their corners and edges, and form a loosely porous, open, spongy mass, entirely pervious to the draught. The residuum does not readily melt into a tough dark slag, such as some coals produce, which chokes the grate of the furnace, clogs the interstices of the fuel, and interferes seriously with the combustion, permitting at the same time the bars of the grate to go rapidly to destruction.

In point of purity, or freedom from earthy matter, these coals of the W. end of the Mahanoy and Shamokin Coal-field will take rank with the very purest to be met with in the anthracite country. This is confirmed by chemical analysis. The lowest bed of all, and the two upper large ones of the sandstone series, are remarkable for the small proportion of ashes which they yield. The entire freedom of all the coals from sulphur is an attribute not less distinctive, and is an important recommendation to their employment in the smelting of iron, and in the furnaces of steam-engines. The hydrogen of the gaseous part of the coal is a potent purifier, or remover of any sulphur with which either the iron ore or the coal itself might be contaminated. The excellence of the iron of the bituminous blackband ore of Scotland is admitted to be due to the purifying influence of the hydrogen of its bitumen.

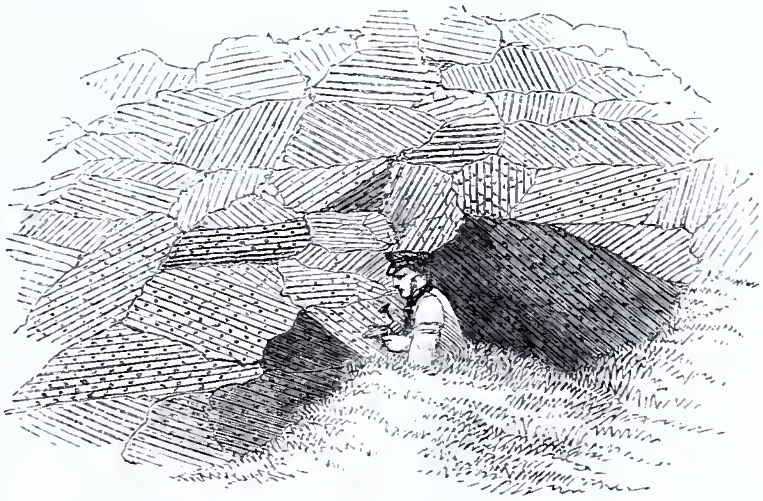


Fig. 250.—View of the Top Slate of Coal No. X., near Zerbe's Gap, Trevorton, showing matted flattened stems of Sigillaria.

DIVISION IV.

NORTHERN ANTHRACITE COAL-FIELD, OR BASIN OF THE LACKAWANNA AND NORTH BRANCH OF THE SUSQUEHANNA.

CHAPTER I.

TOPOGRAPHICAL FEATURES, COMPOSITION OF THE STRATA, AND GENERAL STRUCTURE OF THE BASIN.

FORM AND INTERIOR FEATURES OF THE VALLEY.

Like the other anthracitic coal-fields of Pennsylvania, this large and rich basin of the Lackawanna and North Branch of the Susquehanna is surrounded by a double belt of mountain-summits ; but instead of that usually entire separation of the inner and the outer ridges which is so conspicuous in the Pottsville, the Shamokin, and other coal valleys, the intervening deep narrow valley of Umbral Red Shale is here only a high sloping platform or bench on the side of the exterior mountain, and the interior crest is but a subordinate ridge or shoulder between this bench and the main valley. This feature in the encircling high lands, of a coalescing of the two parallel ridges into one mountain mass, grows more and more obvious as we advance N.E. along the Wyoming and Lackawanna Basin, increasing as the soft shale-formation, which produces the valley between the ridges, lessens in thickness, and as the dip of the strata, another influential condition, becomes progressively flatter. Towards the W. end of the basin, where the easily excavated Red Shale, and the soft sandstones belonging to it, hold a thickness of several hundred feet, and where, moreover, the inclination of the strata is as steep as from 30° to 45°, we may discern from any high points, like those overlooking Solomon's Gap, the distinct division of the enclosing mountain into its two crests ; but from Wilkesbarre N.E., and especially between Pittston and Carbondale, where the shales thin down, and at last almost disappear, and the dip declines to no more than 10° or 12°, this separation grows to be very dimly defined, except just where—as in the upper valley of Stafford Meadow Brook and its prolongations—the waters which have ploughed the surface have been assisted in cutting a deeper longitudinal trough than ordinary, by the extra strength and keenness of current imparted to them through the existence of transverse notches promoting their rapid outflow.

The coal-field, or trough of the coal-containing strata, encompassed by this picturesque mountain-rim, is a very elongated valley, some 50 miles in length, from Beech Grove to Carbondale, and not more than 5 miles wide in its broadest central portion, between Solomon's Gap and the entrance of the Susquehanna at Pittston. Its form is that of a very regular symmetrical crescent, curving in its course as much as 50°—the N. horn at Carbondale pointing about N. 20°

E., while the W. one at Beech Grove is directed only 20° S. of W. In its interior features this valley is extremely diversified, and is full of landscapes of uncommon beauty. From Pittston to Nanticoke, or between the points where the Susquehanna enters and leaves the basin, the N. half of the main bed of the valley is a wide level fertile plain, or low diluvial floor, watered by the tree-fringed river. A similar but narrower belt of low ground, underlaid in like manner by a deep deposit of drift or gravel, winds through the whole length of the upper N.E. portion of the valley, or that occupied by the Lackawanna. Everywhere else between these river-plains and the flanks of the bounding mountains, and throughout the W. end of the basin, its surface is undulated with a multitude of approximately parallel chains of hills and denuded ridges, which, in nearly all the district between Beech Grove and Wilkesbarre, are sharp-crested, steep, and much ravined and cut, but show wider summits, and softer slopes and outlines, progressively, as we follow them towards the Lackawanna and ascend its valley. This change of feature is very striking when we contrast the long, steep-sided, narrow-backed ridges between the S.W. end of the valley and Solomon's Gap, with the wide, flat-topped, or gently-sloping plateaus between the falls of the Lackawanna and Carbondale.

GENERAL VIEW OF THE STRATA.

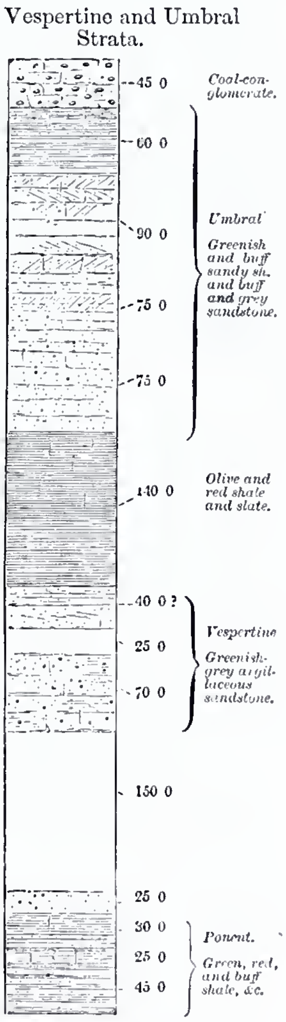

Vespertine and Umbral Strata.
45 0
Coal-conglomerate.
60 0
90 0
Umbral
Greenish and buff sandy sh. and buff and grey sandstone.
75 0
75 0
140 0
Olive and red shale and slate.
40 0 ?
25 0
Vespertine
Greenish-grey argillaceous sandstone.
70 0
150 0
25 0
30 0
Ponent.
25 0
Green, red, and buff shale, &c.
45 0

Fig. 251.—Cobb's Gap, of Roaring Brook.—1 *inch* = 200 *feet*.

Taking a comprehensive survey of the several rocky strata which surround and are embraced within the Wyoming and Lackawanna Basin, they will be found to constitute four distinct groups, differing in their positions and composition, and in the value of their imbedded deposits. As the Sections will show, they are inconstant in type and thickness.

1. The first and lowest in the order of stratification is a thick series of grey sandstones, occasionally pebbly, and including beds of shale. This outcrops high on the inner slope and summit of the outer broad mountain-ridge of each border of the basin. The formation is several hundred feet thick, but is variable in size and type, as the columnar Sections here given will show. It is the lowest or oldest of our American carboniferous strata, but in this part of the mountain-chain of the country it contains no coal, nor any notable amount of iron ore. It is our Vespertine series.

2. Next in succession, overlying this formation, and outcropping usually in a high bench, but sometimes in a valley, following the inner slope of the outer or main mountain all round the coal-basin, occurs a mixed group of strata, red shales in the inferior portion, grey sandstones and buff-coloured slates in the middle, and a peculiar hone-like very close-grained calcareous sandstone in the upper. Such is the character of this Umbral formation in the vicinity of Scranton, and elsewhere on the borders of the Lackawanna division of the basin, where its total average thickness does not amount to 350 feet, and where the Red Shale of the lower member of the mass is extremely thin, and in places altogether absent. But further S.W., especially between Solomon's Gap and Beech Grove, the Red Shale assumes great relative bulk, and the middle and upper divisions, as at Nanticoke, are comparatively much reduced, the whole formation being from two to three times as thick as where it

bounds the Lackawanna Valley. It is among the layers of the lower or shale group of this formation that we encounter the interesting *calcareous iron-ore* of the Stafford Meadow Valley, once extensively mined on the Lackawanna Iron and Coal Company's lands, and smelted in the furnaces at Scranton. The whole formation is the Umbral series, or middle carboniferous formation. To the easily-worn nature of its shaly beds, contrasted with the far superior resisting powers of the Vespertine sandstones beneath them, and of the equally hard middle and upper members of their own formation, supported by the still more massive and cohering conglomerates of the base of the Coal-measures just overlying these, we must attribute the prevalence of the mountain valley or broad bench on the mountain-side, already described as so general a feature along the outer edge of the coal-field. The cuts here presented display its variability of composition.

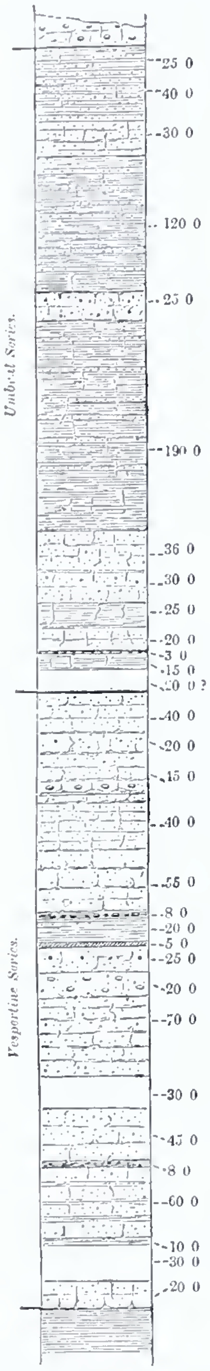


Fig. 252.—Vespertine and Umbral Strata at Solomon's Gap.—1 *inch* = 200 *feet.*

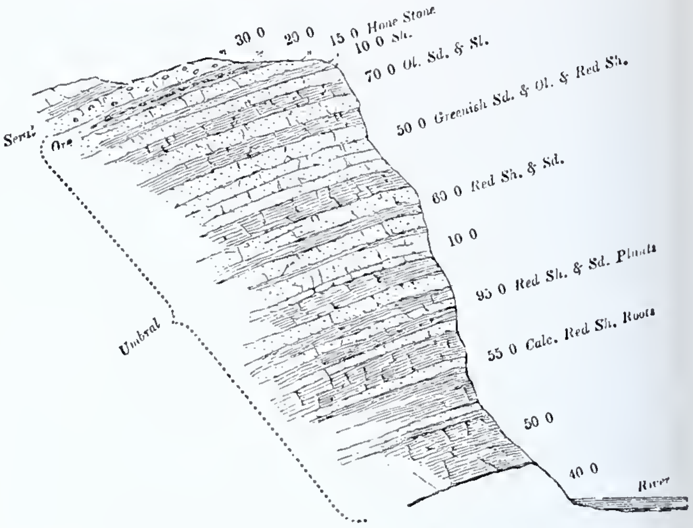


Fig. 253.—Umbral Red Shale, Nanticoke Mountain, at Nanticoke.—1 *inch* = 200 *feet.*

3. Immediately over the fine-grained, hone-like sandstone of the top of the Umbral series rests the Seral conglomerate of our classification, a coarse massive white-and-grey conglomerate, constituting the base or supporting member of the productive Coal-measures, or upper carboniferous series. All round the Wyoming and Lackawanna coal-field, this well-known and easily-recognised rock is composed of two sets of strata: a lower group, made up in large part of extremely coarse pebbles of nut size, of white quartz and grey sandstone, compactly cemented into thick and ponderous beds; and an upper group, of less massive layers of a smaller-grained conglomerate and dark-grey sandstone, the pebbles seldom exceeding the size of a pea or small hazel-nut. The average thickness of the lower mass on the S.E. side of the basin is from 70 to 80 feet, whereas on the N.W. side it seems nowhere to exceed 40 feet; that of the upper fine-grained rock varies from 60 to 90 feet, but shows no such marked reduction in passing from its S.E. to its N.W. outcrop. At Scranton, on Roaring Brook, the coarser rock is about 80 feet thick, and the finer grained, which is here quarried, and makes a valuable strong building-stone, is about the same thickness. In some parts of the anthracite coal region, and possibly in certain localities on the borders of the Wyoming Basin, indications exist of the presence of a bed of coal in the shales which sometimes separate these two divisions of the conglomerate. This fact, and the identity in composition of the upper member with the coarser grits of the true Coal-measures, induces me to class it as a part of these, though, as it usually lies below any workable coal, it may equally retain its place as a division of the conglomerate upon which it directly reposes, and into which it in many places graduates. In fact, a comprehensive study of the lower coal strata, and of the conglomerates interstratified among them, distinctly shows

that even the main undermost coarsest pudding-stone, or Seral conglomerate, is itself properly but a member of the true Coal-measures, and in no sense an independent formation. There are, as we have already seen, several districts in Pennsylvania where productive coal-seams occur imbedded within this coarsest lowest mass, and others indeed where such exist even beneath or outside of it.

It has been the superior firmness of cohesion or solidity of this rock, compared with that of the softer overlying Coal-measures and underlying Umbral group, both abounding in slates and shales, that has enabled it better to resist the tremendous furrowing action of the waters which carved the land into its present inequalities, and caused it to stand out above the deeper-ploughed surfaces of those formations. Wherever a notch or breach through the conglomerate and a considerable steepness of dip have promoted a deeper than usual grooving of the Umbral shales behind it, this coarse rock rises forth in a more or less ragged and naked crest, forming the inner of the two mountain-summits already mentioned as bounding the coal-basin; but where the denudation has been more uniform down the mountain-side, and the inclination of the strata is gentle, it forms rather the front or supporting edge of a horizontal or sloping shelf than a separate ridge. The edge of this mountain shelf or ridge, as the case may be, is the readily distinguishable boundary of the productive Coal-measures, the lowest notable coal-bed usually outcropping on the valley-side some distance below the slanting ledge of naked coarse pebble rock. Where the dip is extremely flat, however, and the conglomerate uncommonly thin, the last coal-seam will often have its margin or outcrop almost as high on the mountain-side as the pudding-stone, but it then outcrops at a still wider interval inside of that rock. This latter state of things prevails in the vicinity of Scranton on Roaring Brook, and elsewhere on the S. side of the coal-basin. The average dip of the strata N.W. does not there exceed from 3° to 5°; and as about 100 feet of lower Coal-measures, embracing two or three thin coals, intervene between the top layers of the upper conglomerate and the lowest seam worked, the horizontal space between the pebbly rock and this coal-bed is often 800 and sometimes 1000 feet. To determine, therefore, the true limits of the available coal-lands of a district by the position of the exposed outcrop of the conglomerate, in default of sufficient openings in the coal itself, demands a nice attention to the several circumstances of the rate of dip, the thickness of the interposed strata, and the features of the denudation, or of the washing away of the overlying coal-containing rocks from off the barren floor of conglomerate.

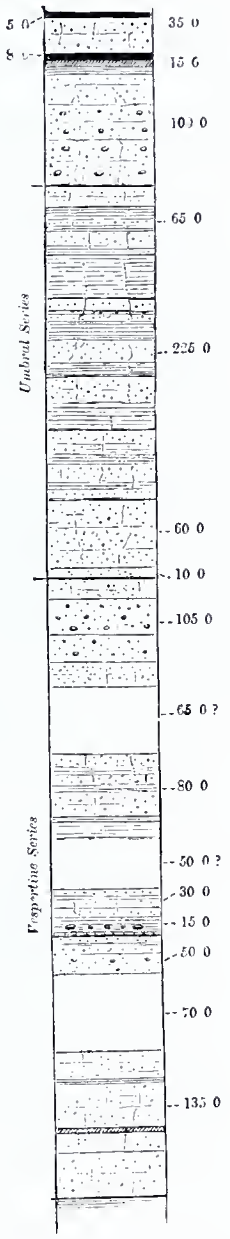


Fig. 254.—Vespertine and Umbral Strata, Hertzoff Hollow, N. of Kingston.—1 *inch* = 200 *feet*.

4. The last and highest of the formations of the region in the order of stratification is the Coal-Formation proper. In the Wyoming and Lackawanna Basin, this consists, as is well known, of coarse and fine-grained grey micaceous sandstones, pebbly in some of their beds; and of argillaceous sandstones, shales, slates, and fireclays—some more silicious and gritty, some more aluminous and smooth;—and between all these are interstratified beds of anthracite of all dimensions, from a few inches to many yards in thickness. All the coal-seams, with one or two very local

exceptions, yield either white or grey ashes; and as in the Pottsville and Shamokin basins the coals of this character are overlaid by a group of beds, producing red and brownish ashes, such as are not here met with, it is fair to infer that in this Wyoming Valley we have the representatives of only the White-Ash and Grey-Ash groups of the other great basins. Denuding action, which has been especially powerful here, may have swept off the once overlying and more exposed Red-Ash series, or these possibly may never have been formed in this Northern district.

It is impossible to estimate with precision the total thickness of the Coal-measures in the deepest parts of the Wyoming and Lackawanna Basin, or to count with accuracy the number of the available beds of coal in those localities; but exact measurement discloses in the vicinity of Wilkesbarre—the widest and apparently the deepest portion of the coal-field—the existence of from 1000 to 1200 feet of coal-bearing strata, and the presence within these of *sixteen* or *eighteen* separate beds of coal; two or three of these being compound seams of great size, and some ten or more of the whole series being permanently of ample dimensions for profitable mining. This depth of the Coal-measures, and number of the contained coal-seams, grows less, of course, from the centre of the basin towards its two margins, and also towards its two contracting extremities.

As a provisional classification convenient for present reference, the whole body of the Coal-measures, or coal-containing strata of the basin, may be divided into two groups—*first*, a *lower series*, comprehending all the coals, some nine or ten in number, great and small, from the Seral conglomerate to the highest of the set embracing the great Wilkesbarre or Baltimore Company's seam; and *secondly*, an *upper group*, of about seven or eight beds in all, commencing with the large Pittston or Fourteen-feet bed as a base, and terminating with the Four-feet Coal of the immediate vicinity of Wilkesbarre, the uppermost whose position I have yet positively determined anywhere in the coal-field. It is proper to observe, that while the lower group contains, where it is fullest and best exposed, some ten independent coals, there are usually not more than five of these of such dimensions and purity as to fit them for profitable mining; while from the great fluctuations in both of these conditions to which this series of coals is liable beyond all other divisions of the whole coal-formation, there are districts where no more than two or three of the beds are large enough and good enough to prove of any commercial value. In like manner, while the upper group includes of large and trivial beds as many as seven or eight, there is no neighbourhood where more than four of these are of suitable size and quality for working, and in some localities the number of such is even fewer.

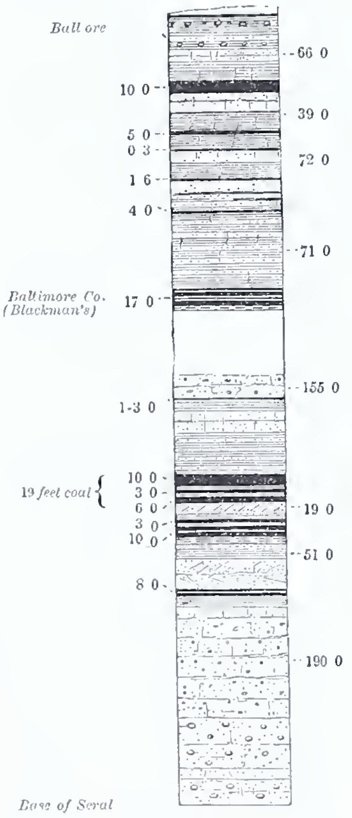


FIG. 255.—Wilkesbarre Lower Coal-measures near Solomon's.—1 *inch* = 200 *feet*.

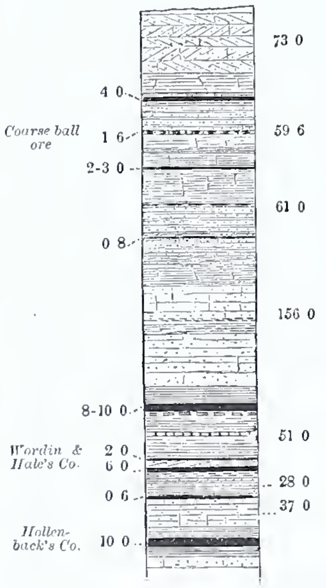


FIG. 256.—Wilkesbarre Upper Coal-measures (mouth of Mill Creek).—1 *inch* = 200 *feet*.

As regards the limits and distribution of these two divisions of the Coal-measures within the basin, it suffices, for our present purpose of a general comprehensive survey, to recognise the fact, that the upper group is restricted to a comparatively short and narrow elliptical belt in the very central tracts of the coal-field, its S. margin passing through the low grounds S. and S.E. and E. of Wilkesbarre, and by the valley of Laurel Run and White Oak Hollow to the S. of Pittston, and the whole of this basin of the upper measures terminating some 2 miles to the N.E. of the mouth of the Lackawanna River (see its boundary on the Map). On the other hand, the lower series occupies the entire area of the coal-field underlying the small central basin of the upper group, and emerges to the surface all round it, one broad outcrop filling the whole S.E. side of the valley from the margin indicated, to the S.E. conglomerate barrier, and another, the N.W., to the same terminating rock on the opposite mountain. Below Nanticoke and above the vicinity of Pittston, or throughout the Lackawanna Basin, these same great lower coals fill the whole breadth of the valley from mountain to mountain, unconcealed by any overlapping beds of the upper set.

GENERAL STRUCTURE OF THE BASIN.

In order to convey a correct conception of the conditions under which the coal-beds and coal-rocks of this valley lie, and their accessibility for mining, it is expedient to refrain a little longer from local descriptive details, and proceed to a few preliminary considerations respecting the general geological structure of the whole coal-field. We shall be thus prepared to understand much more precisely the peculiar distribution of the coal.

In its general configuration the Wyoming Basin is a wide and shallow trough, somewhat deeper in the middle than at the sides, yet descending so gradually as to be, if we disregard the subordinate undulations of the strata, approximately flat towards the centre. This prevailing levelness of its bed or floor, notwithstanding the considerable angles of dip—at the margins frequently more than 30°—is at once apparent when we compare the great width of the valley, 4 or 5 miles in its middle district, with the very moderate depth of 1200, or 1500, or perhaps 1800 feet, which the sections seem to assign to it, in this its most capacious portion. Laborious explorations and measurements have enabled me to bring to light within the general basin the existence of a great number of nearly parallel lesser troughs or basins, with intervening saddles or anticlinal waves in the coal strata, and to trace these individually, and develop the law of their direction, and their effects on the local distribution of the beds of coal. These investigations have shown that the same coal-seams and other strata are repeated, within certain limits, from one wave to another, so as to maintain, despite the local steepnesses of dip, one average uniformity in the depth of the coal-field at any given cross-section. This general levelness of the bottom is independently established by a comparison of the vertical thickness of the strata at many points within the valley.

The whole coal-valley may be likened to a flat-bottomed boat, tapering gradually from the middle towards both extremities, and as gradually shoaling up in those directions; though the boat is not a straight one, but curves constantly, crescent-like, towards one side, and the resemblance is further deficient in the bottom not being smooth, but ridged with the waves above spoken of. This shoaling or thinning, by superficial removal, of the Coal-measures, towards either end of the trough, though within restricted limits locally modified by the undulations, is not a uniformly progressive feature, but advances suddenly, and then more slowly, along certain portions of the valley. Thus it seems to proceed rather rapidly from Wilkesbarre N.E. past Pittston, and to be almost arrested, thence along the Lackawanna Valley from near the mouth of Spring Brook, until we pass beyond Scranton, while a more rapid lifting-out of the strata seems again to commence near Legget's Gap, and to continue steadily to the termination of the basin at Carbondale. This fact of the very slow rise of the coal-rocks as we ascend the Lackawanna from the Falls to a mile or more beyond Scranton, would seem, at first glance, to nearly equalise the quantity of available coal for equal areas throughout this reach of the valley; but a detailed examination of the comparative resources of the several tracts of this district discloses quite remarkable differences, dependent on various conditions not connected merely with the depth of the Coal-measures. Among these modifying circumstances, those of conspicuous importance are, the variations in the number, thickness, and purity of the coal-beds within the same mass, or thickness of coal strata; the comparative quantities of minable coal above the beds of the ravines and valleys, the accessibleness of the coal to economic mining and ready drainage, as affected by the direction and degree of dip of the strata, and the greater or less extent to which the strata, and especially the seams of coal, are obscured, preventing successful mining, or concealed altogether from discovery by the very unequal covering of drift or gravel which hides from view large patches of the coal-formation in this part of the basin. So influential are these and other conditions on the productive capacity of any given tract, that it may be said that a different mining value characterises every different half square mile of the valley, rendering it quite unsafe to infer from the ascertained geology and resources of one range of land, the commercial value of grounds adjoining, unless these have been themselves carefully and experimentally opened, and the specific relations of the unknown portions to the known, well established. Circumstances seemingly the most trivial—as, whether with a gentle dip the coal-beds lying above the water-level of a valley incline *into* the hill or table-land which bounds it, or *outwards* towards the low grounds, determining whether machinery must be or need not be used—will oftentimes make a difference in the economy of mining the coal equivalent to the whole margin of average profit to be anticipated; and therefore no speculative anticipations beyond very vague and general ones are to be built upon any generalisations extended to unexplored lands, from those where the geological structure, mineral contents, and mining capabilities are already ascertained.

UNDULATIONS OF THE BASIN.

There are several features connected with the undulations of the Coal-measures in the Wyoming and Lackawanna Valley, which claim attention in any general survey of the structure and mining capabilities of this basin, or in any comparison of the resources of its different sections. Some of these concern the directions of the undulations with respect to each other, and to the course of the general valley which contains them; while others belong to the forms of the undulations, and the law of their steepening and subsiding.

1. The feature of widest generality connecting these anticlinal and synclinal waves, or saddles and troughs of the strata, is their remarkable approximation to parallelism throughout the entire range of the basin, irrespective of the bending course of the Main Valley and its

including mountains. This constancy in the direction of the waves, though singularly close, is not absolute, when those of distant sections of the valley are compared, there being a difference between the anticlinals of the vicinity of Wilkesbarre and those of the Lackawanna Valley of some 6°, the former ranging about N. 67° E., while the latter observe an average course of N. 72° or 73° E. ~~It is, however, with few exceptions,~~ strictly maintained among the flexures of the same district.

As a natural consequence of this approximate permanency of direction of the undulations, and the curving outline of the general basin, it is only in the lower or W. end of the valley that these rolls of the strata are parallel, or even nearly so, within the main course of the valley. There the chief groups among the anticlinals approach to a coincidence in direction with the mountain forming the S. side of the basin. Advancing N.E. to the Wilkesbarre and Pittston districts, this parallelism with the mountain border is more and more departed from, and with its progressive deflection to the N., along the S.E. side of the Lackawanna Valley, the obliquity of the undulations to the line of the basin and its barriers grows conspicuously greater. From the vicinity of Wilkesbarre, and probably from further W. the whole way to Carbondale, these anticlinals come forth in succession from the mountain-sides of the valley at larger and larger angles as we advance towards the N.E., the anticlinal waves, broad and flat on the slope of the mountains, pointing down obliquely W. into the valley, and contracting and growing steeper; while the synclinal troughs between them rise out of the central bed of the basin, flattening and shoaling up to the E., to disappear at higher levels on the same mountain-sides. This arrangement is discernible in the undulations of both sides of the basin, but those of the S.E. side being more numerous, of steeper flexure, and less obscured by diluvial drift, the feature is there more conspicuous. Each of the two mountain-barriers of the valley, with its set of anticlinal spurs passing off from it at successively increasing angles, may be likened to a curving fish-back, one concave, the other convex, sending out its spines or rays at increasing obliquities, but in mutual parallelism with one another.

2. A further general fact connected with these undulations of the Coal-measures—interesting for its geological bearings, and not less so for its practical consequences—is the curious declining gradation observable in the sharpness of the successive undulations as we proceed from S.W. to N.E. along the basin. Not only does each anticlinal of the S.E. side of the valley grow gentler or flatter in its dips as it slowly rises to the E., but the successive ones are fainter and fainter at the same proportionate sections of their length as we cross them obliquely in going towards the N.E. Those of all the lower or W. end of the valley, from Beech Grove to Nanticoke, show inclinations as high as 45°; those between Nanticoke and Wilkesbarre display dips exceeding 30°; and those between Wilkesbarre and Pittston, dips averaging 20° or 25°; while, following the Lackawanna division of the basin, we have no longer anything approaching this last steepness of flexure—except just near the ends of the saddles—but rather a low broad waving of the rocks, growing feebler and feebler as we advance, until, passing Scranton into the district between it and Archbald, regular undulations become almost imperceptible, and are lost in the very gradual dips into the middle of the general trough from the two borders of the valley. Accompanying this progressive smoothing-out of the waves or corrugations of the strata from the S.W. towards the N.E. end of the whole basin, there is a like gradual transition of declension in its external features, from sharp and narrow-crested ridges and deep hollows to

rounder and gentler spurs and valleys, and along the Lackawanna to wide-topped summits, bluffs, and open denuded plains.

3. Other points of general structure, appertaining to the interior undulations of the main basin, have reference to the prevailing *form* of the anticlinals and their troughs. A main feature in the individual waves is a progressive increase of flexure, or a steepening of the dips on both sides of the anticlinals as they advance from the mountain-sides, where they originate, out into the central tracts of the valley to near their terminations, which are therefore comparatively abrupt. Remarkably clear exemplifications of this structure present themselves to any close observer of the anticlinals between Wilkesbarre and the Lackawanna. If these be carefully traced from the E. down to this district, they will be seen to grow steadily sharper and sharper in their dips, until they approach in their oblique course to the banks of the Susquehanna, in the neighbourhood of which they nearly all subside by bluntly rounding off. In proof of this abrupt cessation, we have only to remark the contrast between the general steepness of these undulations, where they are crossed slantingly by the old stage-road, or even by the plank-road, and the extreme gentleness and absolute disappearance of many at the canal, and especially at the shore of the river. The very position in the valley which the river has taken, between the mouth of the Lackawanna and Wilkesbarre, is an evidence of the sudden dying-out of this Southern system of anticlinals. It would seem as if the waters, in scooping the lower valley or plain within which the Susquehanna flows, had been unable to pass the succession of barriers presented to them by these ridges in the strata, and were forced to recoil by the N. flanks and bold ends which the saddles protruded against them, swinging off in their rebound to follow the deflecting course of the waves of the strata towards the outlet of the drainage of the valley, the wide notch in the Northern mountain-barrier at Nanticoke.

The N. or N.W. side of the valley appears to have its own set of anticlinals or saddles, as already intimated; but whether these observe the same law in their oblique descent into the valley from the W. of a progressive increase of dip on both their flanks, I am not prepared at present to maintain, as the structure of this portion of the valley is largely disguised by surface drift, and as the points of many of the spurs or saddles are hid by the deep diluvium of the Wyoming and Lackawanna flats. All analogy, and every theoretical consideration of the origin of this curious feature in the anticlinals, would indicate, however, that the same steepening towards their terminations belongs to these waves, which characterises those coming from the opposite mountain lying E. Whether any of the flexures of the upper strata cross the basin entirely, passing W. from the Southern Mountain to coincide with undulations proceeding E. from the Northern, cannot be at present known; but the general cessation of both sets towards the middle of the basin is a strong intimation of the improbability of such a condition. The wood-cut here introduced displays one of the small flanks of the N. side of the basin known as Campbell's Ledge. It is a roll in the Seral conglomerate, exposed in the E. side of the gap of the Susquehanna. The face of the cliff, ranging nearly N. and S., is called also the Dial Knob.

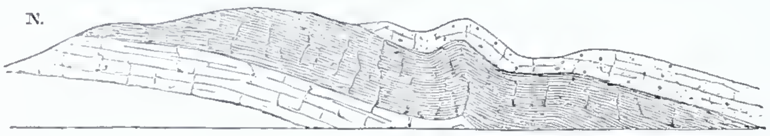


FIG. 257.—Campbell's Ledge above Pittston, Susquehanna Gap.

4. Besides the long parallel tapering anticlinal waves coming very acutely off from the mountain-borders of the basin, there are numerous shorter and narrower ones, having the form

of oval keels or saddles, which do not run into the mountains, but lie more or less insulated. Undulations of this class are more frequent in the central tracts of the valley than towards the sides, and their relative proportion to those of the longer form seems to increase steadily towards the upper or N.E. end, becoming between Scranton and Carbondale rather the prevailing type. In the uppermost parts of the Lackawanna Basin, we may indeed generally describe the flexures of the strata less as continuous waves or ridges than as successions of these elongated elliptical swells, some of them bulging into considerable steepness, but the chief part of them low and gentle waves, often too obscure to be detected externally in the topography, or in the dipping of the rocks, yet obvious in the mining of the coal, over which the feeblest undulations exert an almost tyrannic control, as regards the directions of the levels and gangways within the mines. It is a consideration of this important connection between the forms of the crust-waves and the whole economy of mining in our undulating coal-fields that induces me in this place to dwell so minutely on the several shapes which these assume.

5. There is still a lesser class of undulations in the coal-rocks, which the progress of mining in the region is constantly bringing to light, and which demand some mention here. These are the small irregular subordinate rolls, or short and narrow, but not always flattish wavings of the strata, on the flanks of the principal anticlinals. In some districts of the anthracite basins, these secondary flexures, whether on the backs or sides of the main saddles, or in the troughs between them, are for the most part parallel with the principal undulations which support them ; but in the Wyoming and Lackawanna Coal-field, and other regions of oblique anticlinals, they are themselves acutely oblique to the axes of the great waves which sustain them. Their arrangement is somewhat analogous to that of the small feathers or plumelets on the side of a bird's wing; while the whole wing diverges and tapers from the body of the bird—the mountain boundary of the basin—these lateral lesser plumes diverge and taper in their turn from the main direction or axis of the wing. Wherever this structure prevails in its fullest symmetry, the mine levels or gangways, when extensive, will, in winding in and out on the sides, or at the foot of a chief anticlinal ridge, have that variety of the scallop form which we may call oblique, the convex loops all pointing in one direction—that, namely, towards which the main anticlinal is itself subsiding. These secondary rolls are numerous in the Great Mine of the Baltimore Company, near Wilkesbarre.

6. Viewing the undulations of the Wyoming and Lackawanna Coal-field transversely or in profile, they exhibit in the main the same feature of a preponderating steepness of dip on their North-western sides which characterises the chief part of the secondary flexures of the Pottsville Basin ; but inasmuch as all the inclinations of the rocks of this Northern district are far gentler than those of that Southern coal-field, in the same proportion is the inequality less in the slopes of the opposite sides of the anticlinals, until, in the Lackawanna Valley and other very gently undulated districts, the difference in an average of several waves is almost imperceptible. The general trough-like structure of the valley in these sections disputing its influence on the inclination of the strata with the local flexures, the undulations of the S.E. side of the basin show their steepest dips to the N.W., or towards the bed of the valley, while those of the N.W. side exhibit theirs on their S.E. flanks, or towards the same controlling synclinal line. In the W. end of the Wyoming Valley, the undulations being there sharper, the general law of inequality in the slant of the sides of the waves is much more conspicuous than in the

Lackawanna Valley, where all the flexures are flatter, and where local swells have a relatively greater power to disguise the existence of any general law of form in the undulations.

Having in the foregoing paragraphs unfolded as succinctly as was compatible with clearness the general characteristics of the structure of the curiously-fashioned beautiful coal-field of the North Branch of the Susquehanna, it is incumbent on me to offer now a more special and minute description of the better developed districts of the valley.

THE COAL-MEASURES.

It has been already stated that the coal-containing strata of the coal-field generally appertain to the White-Ash Coal-measures of the anthracite basins; and it was also remarked that this group exhibits greater fluctuations in the dimensions and quality of the coal-beds than any other subdivision of the whole coal-formation. These fluctuations, it is appropriate to add, belong equally, or in a greater degree, to the rocks which fill the intervals between the coal-beds. It would seem as if the physical conditions under which these earliest coal strata were deposited, were more inconstant than those which belonged to the later stages of the formation. The spaces over which the nearly perfect state of repose of the surface prevailed, necessary to the accumulation by slow growth of the vegetable peaty mass producing each seam of coal, were evidently of a narrower geographical extent than afterwards; and the currents and disturbances of the earth's crust, which buried these successive peat-swamps under the clayey, sandy, and even coarse gravelly strata that rest upon or between them, were obviously much more violent than in the middle and final ages of the great coal period.

Nowhere, perhaps, in the anthracite country, are the proofs of this instability of the surface during the first stages of the coal-formation more conspicuously manifested than in the Wyoming and Lackawanna Basin. Here we find, in certain neighbourhoods, in the same few hundred feet thickness of the lower coal strata, as many as ten or twelve separate beds of coal, while in other localities there exist not more than half, or even a third of this number; and what is more material, the very same individual bed which in one quarter possesses an ample or indeed superabundant thickness, is in another only a dwindled seam, too thin or too impure for profitable mining. Without attempting any close continuous tracing of the several coals, which can only be done when the district shall have become much more extensively mined, I may exemplify the variability of these Coal-measures by appealing to the very different types which they assume in the three meridians of Solomon's Gap, S.W. of Wilkesbarre; Spring Brook, S.E. of Pittston; and the vicinity of Scranton.

At Solomon's Gap, the group of lower White-Ash Coal-measures (see Fig. 255, p. 322), extending from the foot of the mountain N.W. across the basin, to the edge of the diluvial flats of the Susquehanna, includes in a thickness of 900 or 1000 feet as many as *thirteen* beds of coal of various sizes, from 1 foot to 19 feet; and the total thickness of coal, fit and unfit for mining, embraced by this section, may be estimated at nearly 84 feet. But out of this aggregate quantity, the thickness susceptible of being profitably wrought does not probably amount in all to more than 45 or 50 feet. Traced E. and W., these coal-beds undergo, even in the space of 2 or 3 miles, some very remarkable variations. Thus the fifth in position from the bottom enlarges in that distance from a thickness of 17 feet at Solomon's Gap to the noble bulk of 28 feet opposite to Wilkesbarre, beyond which neighbourhood it seems again to decline even more rapidly than towards the S.W. These fluctuations arise partly through the coalescing of two or more beds into one, or, conversely, through a splitting and diverging of the thicker seams into two or three thinner ones; or partly, again, by the gradual alterations of size of the same coals, independently of such unions and subdivisions.

If we turn now to the district of Spring Brook, we shall find all the features of the formation so altered as to present not one subdivision, neither coal-bed nor other stratum, which we can recognise or identify as a member of the series visible in the vicinity of Solomon's Gap. In a total thickness of several hundred feet of Coal-measures, embraced between the outcrop of the Main Pittston Seam and the conglomerate of the mountain to the S.E., only six coals in all, according to the largest estimate, have ever been brought to light, after close and persevering researches, and only two of these appear to have a size and purity adapting them for successful mining. There would seem to take place between the neighbourhood of Solomon's Gap, or Wilkesbarre, and this quarter, a progressive impoverishment of these lower strata in the number and size of their included coal-beds, and likewise in the rocks themselves, which thin down considerably. As a consequence, this portion of the Southern skirt of the valley contains no collieries of any magnitude.

Another and opposite change back to a very productive condition of the Coal-measures, is exhibited as we continue our progress along the same side of the basin N.E. up the Lackawanna Valley to the vicinity of Scranton.

We proceed now to a detailed examination of the basin, beginning, as usual, at the N.E. extremity, and proceeding towards the S.W.

Subdivisions of the Coal-field.—The whole Northern coal-field thus sketched may, for convenience, be subdivided into five districts, the limits of which are, however, somewhat arbitrary. Proceeding from N.E. to S.W. these are:—

1. *The Carbondale and Archbald District.*—This extends from the N.E. extremity of the basin, 7 (?) miles above Carbondale, to the vicinity of Jessup, W. of Archbald. It is 15 or 16 miles long, and expands from a narrow point to a breadth at Archbald of more than 4½ miles. Though wide, it is obviously very shallow, containing even at its lower end only from 300 to 400 feet of thickness of the coal strata, and in some belts much less. Its flat floor is gently and irregularly undulated, the anticlinal flexures in some places, as at Archbald, actually lifting the rock below the coal into view.

2. *The Scranton District.*—This division of the basin, in the centre of which is the town of Scranton, lies between Jessup on the N.E. and Spring Brook on the S.W. Its length is about 12 miles, and its average breadth, between margin and margin of the coal-rocks, is not less than 4½ miles. It is traversed by more decided and longer undulations of the strata, its more Southern anticlinal axes being individually traceable. The Coal-measures of this district are deeper than further up the valley, and the number of separate coal-beds amounts in the deepest parts to about ten.

3. *The Pittston District.*—From Spring Brook to Laurel Run a third somewhat natural segment of the coal-field may be recognised, which I propose to call the Pittston District. It is between 9 and 10 miles long, and expands from a width of 4 miles, which it has at Spring Brook, to one of 5½ miles at Laurel Run. It contains its own group of flexures of the strata, which are

numerous, long, straight, closely approximated, and nearly parallel. It differs from the district N.E. of it in containing a higher group of coal-seams, and therefore a thicker body of Coal-measures.

4. *The Wilkesbarre, Nanticoke, and Shickshinny District.*—This rather natural division of the coal-field, extending from Laurel Run to the W. end of the basin, and lying S. of the Susquehanna, has a length of about 18 miles, and contracts from its maximum breadth of 4½ miles at Wilkesbarre to a mere point W. of the intersection of the river. In the vicinity of Wilkesbarre this district embraces the thickest body of Coal-measures within the coal-field, and therefore a greater number of coal-seams, having apparently two or three seams more than belong to the Pittston district (unless, indeed, at Port Griffith). Westward the basin grows more and more sharply undulated, and approaching Shickshinny, its surface, from this circumstance, and from excessive erosion, is roughly and wildly curved and gashed.

5. *Wyoming, Kingston, and Plymouth District.*—This is the slender belt of the coal-field which lies N. of the Susquehanna, or between it and the Shawnee Mountain. Nearly one-half of it is superficially covered with a deep stratum of diluvial and alluvial matter effectually hiding the Coal-formation, while the other or N. half presents a very accessible strip of the Coal-measures at the base and in the gentle much-channelled slope of the mountain. It contains the lower coal-beds moderately undulated by a series of short, rather feeble, parallel anticlinal flexures.

CHAPTER II.

CARBONDALE AND ARCHBALD DISTRICT.

Valley N.E. of Carbondale.—The topographical features of the valley of the Lackawanna above Carbondale are quite simple. Upon either side of the river the land rises in a succession of slopes, with intervening terraces or benches, to the mountain-summits bounding the basin on the E. and W. It is as yet an undeveloped region, and is covered for the most part by a dense growth of forest. But few explorations have been made in this upper district, and they have not led to any very encouraging results. In the absence of reliable data our notice of it will be brief.

From the position occupied by the Seral conglomerate upon Fall Brook, upon the W. or N.W. side of the basin near Carbondale, it would appear to hold its place not far from the crest of the mountain on that side of the basin, as far N. as our general Map of the region has been prolonged. It evidently does not rise out in basin form for some distance further N.; owing, however, to its gentle inclination on both sides of the valley, and perhaps to one or two rolls which elevate the more central trough, the basin must be shallow, and there is little hope of finding in it any great thickness of valuable Coal-measures. On the E. or S.E. side of the basin, the conglomerate found upon the hill-face, among the back streets of the town-plot of Carbondale, passes near the foot of Plane No. 3 of the Delaware and Hudson Company's Railroad, and follows the inner ridge of the mountain bounding the basin on the E.

On lands held by Mr Woodman, situated 6 miles above Carbondale, diggings have been made to find coal. Several seams have been struck; the thickest coal visible did not exceed 5 feet, and displayed a very rough peculiar texture, making it of little value. It is possible that in the progress of research more hopeful results may be attained, though our explorations hold out no very flattering encouragement.

Of the Lackawanna Basin from Carbondale southward.—Coming now to the Carbondale district of the Lackawanna Basin, we are guided to much more satisfactory and positive results by the extensive mine-workings of the Delaware and Hudson Coal and Canal Company. This corporation holds large tracts of land in the valley as far S. as Archbald, where it is also largely engaged in the mining of coal. Between Archbald and Carbondale, coal is transported over a railroad 8 miles in length, so inclined as to permit the cars to run by gravity. Upon the same principle, the empty cars are returned upon another road to the point of departure. From Carbondale the coal finds an outlet to market by a series of planes, and a gravity-road over the mountain to Honesdale, whence it is shipped upon the Delaware and Hudson Canal to the tide-water.

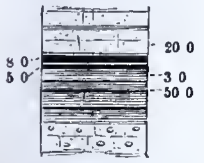


FIG. 258.—Coal-measures at Carbondale. 1 *inch* = 200 *feet*.

By a reference to our column of the stratification in the vicinity of Archbald, it will be seen that there are enumerated the four coal-seams of workable dimensions. Of these only two are found at Carbondale, and upon the upper and larger of the two, mines are established.

Below the great bed are two smaller coals, equivalents of those shown in the Section at Archbald. The lower of these lies close to the conglomerate, and measures 18 or 20 inches. It may be seen near the falls of Fall Brook. The upper is larger, measuring 3½ feet in thickness. It has been found on Racket Brook, near Mr Charles Wurtz's house.

The basin of the Big Coal is a broad and simple one, the dips on both sides being quite gentle, and uninterfered with by anticlinal rolls. Its centre line or axis bears about N. 25° E., and S. 25° W. From the neighbourhood of Shaft No. 2 on Coal Brook, it passes about 300 feet W. of the "New Slope" at the Montrose Road, about the same distance from the "New Mine" Slope, and thence under the plank road, near the crossing of the "loaded" track, to the new mine, No. 3, at the high trestling. From this line it rises out to day on its Westward dip in the bluff on the N. side of the river, where several mine-mouths enter it. Denudation has carried away this valuable coal in the immediate valley of the river at Carbondale, nor is it found in the rising-ground back of the town. Its dip is so gentle that it was found in the hill which supports Plane No. 1, N.E. of the town, and it has been mined to some extent by Mr Clark and others.

Addressing ourselves now to the line of outcrop of the great bed, we may trace it as follows: From a point S. of Shaft No. 2, it occupies the face of the low bluff bordering the flats of the Lackawanna; passing the "New Slope" and the "New Mine," it runs parallel to the river to the "Dip Mine." Thence it deflects Southward, crossing the river, and passes Eastward along the river for about 1000 feet; again it turns Southward for another 1000 feet to the slope of the hill overlooking Powderly Creek. Along this hill-face, from the loaded track at the high trestling, it passes parallel to the creek and the empty track of the railroad to the Powderly branch-road.

It then crosses the valley of the creek above the tunnel, Mine No. 3, and, passing the Powderly Mines, is lost in the high wooded lands to the South. On the N. side of the basin it has been opened near Fall Brook at Brennan's Mines, at the old Fall Brook Mines, and on the S. side of the river, near its brink, at Shaft No. 1 of the Company. Westward of the latter point, on the N.W. side of the river, Meredith has opened it, and it has been proved at several localities between Meredith's and the gorge of Rush Brook 2 miles further S.W. Throughout all this district it retains its dimensions as a valuable bed of coal.

Of the thickness, subdivisions, and character of the great bed itself, we present the following particulars. Taking it at a point where all its component parts are in full development, we have the following :—

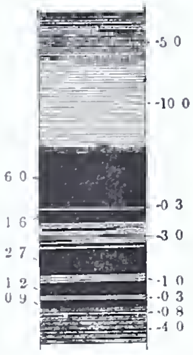


FIG. 259.—Great Bed, Carbondale.

	Feet.	Inches.
Coal and slate in alternate laminæ,	5	0
Slate,	10	0
Coal and slate	1	0
Coal, of good quality,	6	0
Slate,	3	0
Coal,	1	6
Coal, bony (argillaceous), divided by slate,	3	0
Coal,	2	7
Slate,	1	0
Coal,	1	2
Slate,	0	3
Coal,	0	9
Slate,	0	8
Slate and coal,	4	0

The middle slate or bony bench is sometimes only 2 feet thick, but at the Powderly Mines, in the further workings of the old gangways, it amounts to 5 feet in thickness, whereas at the mine's mouth it is not found. At these mines the upper bench of coal is somewhat impaired by bands of slate. We shall presently have occasion to advert to the fluctuations in the dimensions of this coal traced further down the valley. At the high trestling over Powderly Creek, a boring is reported to have been attended with the following results :—

	Feet.	In.
Coarse thick-bedded sandstone—calamite impressions,	16	7
Slate, thin coal in it,	1	10
Coal, pure,	5	7
Slate, compact,	?	?
Coal, pyritous,	2	4
Coal, bony,	2	3
Coal,	1	6
Slate,	0	2
Coal, divided by two thin slates,	5	5
Shale,	...	

At this point the uppermost beds of the conglomerate were found 50 feet below the main coal. Our data place it at the somewhat variable distance of from 50 to 75 feet below the great seam ; and at Archbald it is estimated to be rather more than 100 feet below that bed.

To obviate the necessity of a recurrence to the topic, it will be expedient to define in general terms the position held by the conglomerate on both sides of the valley, as far South-westward as the parallel of Legget's and Cobb's gaps.

On Fall Brook, N.W. of Carbondale, it displays itself at the foot of the falls, where the waters of the stream pour from a great height over its upper beds, capped by coarse grey sandstone. Above the falls it soon rises out in conspicuous ledges upon the E. side of the brook. Many of its beds are unusually massive, and contain pebbles as large as hen's or even turkey's eggs sparsely bedded in a sandstone paste. From this point traced S.W., it occupies a position high on the mountain bordering the valley on the N.W. On every traverse made upon the mountain, it was found to hold this position. Such is the case in the shallow notch W. of Carbondale, through which the road to Scott Township passes. It is likewise found at the water-level in the thorough-cut gorge of Rush Brook, not far N. of the Old Carey Coal-opening, and it has the same place in the wind-gap from which Tinklepaugh Creek descends into the valley. It forms the inner ridge of the mountain at the Greenfield Notch N.W. of Lillibridge's, and throughout the distance to the gap of Legget's Creek it everywhere supports the high ground of the upper rise of the mountain.

Passing now to the uncleared tracts on the S.E. side of the valley, the conglomerate boundary of the basin is much more obscurely defined. It appears to be influenced by several rolls in the strata, which, taking their origin in the mountain, strike obliquely across the valley, at first boldly elevating the conglomerate, but gradually declining, to permit the Coal-measures to wrap round their ends, and fold over their summits. At Carbondale, as we have before indicated, it lies close at the back of the town. It flanks the hill S. of Powderly Creek, where that stream flows longitudinally along the valley, and is found in the neighbourhood of Grinnel's Sawmill, though there are some reasons for believing that it is influenced by one of the anticlinal rolls alluded to, which throws it into the ground again, and produces perhaps a shallow coal-basin in the lands S. of the mill. Above Archbald, and between it and the Great Western Sawmill, we find the conglomerate exposed in massive ledges near the water-level in the hills on both sides of the river, though it again comes out to day as much as 2 miles up White Oak Run, E. of Archbald. There is therefore every reason for believing that coal exists S. and E. of the Delaware and Hudson Company's mines at Archbald. We again find the conglomerate on the old road from Jessup to Cobb's Pond, some distance S. of Noble's or Sterick Creek. From this point, through the wilderness country to Roaring Brook, it has not been followed, though it seems to encroach more upon the valley, perhaps owing to the influence of the great anticlinal of the Dunmore Ridge ; and it appears on Roaring Brook at the mouth of Little Roaring Brook, where we will leave it until we come to describe it in our treatment of the Scranton District.

Of the structural features of the Lackawanna Coal-basin, between the Carbondale district and that of Scranton, we are unfortunately unable to present many particulars. The wide distribution of diluvial matter which conceals the strata on the cleared lands along the river, and the wild and inaccessible nature of the more Southern country, taken into consideration, with the limited amount of mining or exploratory shaftings, greatly interfere with our presenting a clear and connected account of the distribution of the strata.

Between Archbald and the Great Western Sawmill there are indications of a broad flat roll of strata, which brings the true Seral conglomerate above water-level. Of its origin E. we know nothing, nor have we any guide to its character W. In the latter direction, however, its bearing carries it through the high table-land N. of Archbald.

A second disturbance is that encountered in the working of No. 4 Drift Mine. Though it has somewhat the character of an abrupt upthrow of the strata, it is usually considered a fault. In mining coal from the above-mentioned drift, an upthrow of 12 feet to the S.E. was encountered. Following the coal along the uplift a distance of about 440 feet at right angles, it is thrown down S. 60 feet at an angle of 25°. The upthrow and downthrow bear parallel to each other in a direction S. 65° W. The first, crosses near the head of the Upper or No. 2 Plane; the other, near the foot of the same. The true bearing of the anticlinals of this part of the valley is thought to be about N. 70° E., or S. 70° W. Comparing this with the bearing of the main basin at Carbondale which we have given, it will be seen that the difference is about 45°. We have here evidence that the flexures of the two districts belong to different groups: while in the one case the basin appears to emerge from the mountain on the N.W., in the other the anticlinals are prolonged from the S. barrier.

A third anticlinal roll is that met with a few hundred feet S. of the mouth of Laurel Run, where it crosses the river. The prolongation of this anticlinal W. carries it near Water's Sawmill, at Mount Vernon, below which the dips are W., plainly indicating its declension W. The same fact is proved by the deflection of the gangways of No. 1 Mine at Archbald.

Archbald.—The accompanying vertical column of the strata at Archbald, comprising data obligingly furnished by Mr Jones, Superintendent, will exhibit the stratification of the vicinity. The Seral conglomerate proper is a massive rock made up of pebbles of a large nut-size. This stratum is not more than 20 or 30 feet thick. Below it reposes a thickness of fully 30 feet of pure white sandstone. A rock of the same character, and holding the same position, was seen in the notch of Tinklepaugh Creek on the mountain upon the N.W. Below this rock a boring was made at the Great Western Sawmill Dam. A coal 8 inches thick was reached, but no others were met, though the boring was continued many feet. Close above the conglomerate, a thin coal, from 12 to 18 inches thick, has been found. It is to be seen below the "empty track" near Farnum's Mill-dam. This is succeeded by 80 feet of coarse micaceous sandstone, capped by an impure worthless coal 4 feet thick. About 27 feet of sandstone and shale strata intervene between this and the main great bed, which measures not less than 10 feet in thickness. Succeeding the great bed, 30 feet of sandstone strata are found supporting a coal which is sometimes wanting, though at others it exceeds 18 inches in thickness. Upon this rest 7 feet of shale, overlaid by 55 feet of sandstone strata, which brings us to a coal 4½ feet thick, but not generally of good quality. The next coal measures 18 inches, and is separated from the former by 44 feet of sandstone. A thickness of 17 feet of shale brings us to the highest coal of the district. It caps only the highest ground where the structure favours it: it measures 7 feet in thickness, and is of good quality, but is usually too near the surface to be workable. It is the equivalent of the Grassy Island Coal, worked by the slope and the lower shaft at Jessup, and is thought to be the same as that opened by Squire Callender, near his house, on the old turnpike to Carbondale.

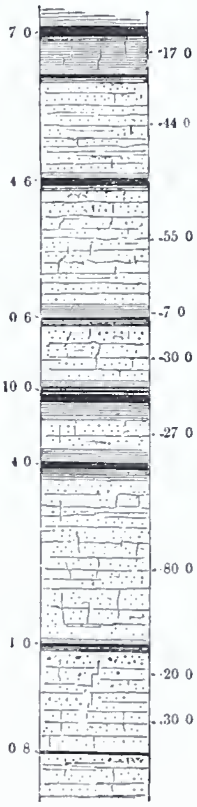


FIG. 260. — Columnar Section at Archbald.

The following are the subdivisions of the main bed at the mines of the Delaware and Hudson Company, and the opening of Mr Hackley at Archbald :—

	Feet.	In.		Feet.	In.
Coal,	2	6	Coal,	1	6
Slate,	0	1½	Slate,	0	2
Coal,	0	6	Coal,	5	0
Slate,	0	2			

We find that the apparent equivalent of the Eight-feet top coal at Carbondale has thinned down to 2 feet 6 inches ; this appears to be owing to the encroachment of the slate upon the coal, which it replaces. In the Powderly Mines there are indications that this is the case. The nett yield in the mines at Archbald does not on an average exceed 5 feet. Over this large seam, upon the N.W. side of the basin, a conglomeritic rock 20 feet thick has been seen ; the same stratum is thinly developed at Hackley's Mine near Archbald, but at the Company's mines it has thinned away.

At Mount Vernon, upon the river, 2 miles S.W. of Archbald, the series of coals indicated in the column have been opened. The lowest bed proved is the equivalent of the Four-feet Coal. It measures 9 feet, inclusive of a band of slate from 18 to 24 inches thick, which divides it. The whole bed is slaty, though parts have been selected for mining. Its place is above the sawmill dam. In the slates beneath this coal, immense nodules of iron-ore are met with, sparsely scattered and firmly imbedded. The second bed is opened behind Mr Water's barn. At the outcrop it is but 4½ feet thick, but in the mine it measures upwards of 6 feet. On the W. side of the river, at about the same level, a large coal has been proved, but not for its entire thickness. It is thought to be the large bed. Iron ore has been found under this bed. About 30 feet above the last bed a 3-feet coal-seam has been proved, and high on the hill the upper coal, 6 feet thick, has been found.

At *Jessup*, situated near Grassy Island Creek, about a mile from Mount Vernon, are located the mines of the Lackawanna Railroad Company. The upper 7-feet coal, entitled the Grassy Island bed, and the lower main seam (the Seymour beds), are wrought. They are separated by 180 feet of strata. The upper shaft, now abandoned, penetrated 165 feet to the Seymour Coal, in which it displays the following dimensions :—

	Feet.	In.		Feet.	In.
Coal,	0	8	Coal,	4	0
Slate,	0	3	Slate,	0	6
Coal,	2	0	Coal, purest,	2	0
Slate and Coal,	0	8			

In the lower shaft, the upper coal was met at a depth of 18 feet. Both of these shafts were located upon a Northward-dipping bed, and owing to this mistake in the lower shaft, the Company were under the necessity of sinking lower, and tunneling forward to the coal, in order to gain a working breast. The tunnel was driven at a depth of 40 feet. A slope-mine enters upon the same seam at the head of the lower shaft. The dip in this slope is 9° at the top, steepening to 14°.

The following are the subdivisions of the upper or Grassy Island Coal :—

	Feet.	In.		Feet.	In.
Coal,	1	6	Parting,	...	
Slate,	2	6	Coal,	1	0
Coal,	1	2	Slate,	3	0
Parting,	...		Coal,	1	0
Coal,	3	4			

It crops out near Jessup on Grassy Island Creek, whence its name.

The lower shaft was sunk 160 feet below the upper coal, to a coal-bed 3 feet thick, supposed to be about 20 feet over the lower bed.

The Seymour Coal bed crops out on the S. margin of the flat ground back of Jessup, but in its course South-westward it gradually climbs the hill. On the E. end of the same hill, the Seral conglomerate crops out at the Grassy Island Creek. On Noble's or Sterick Creek, back of this hill, a small coal is found making the bed of the stream ; it is one of the lower coals.

The basin of the Jessup Coals is estimated to be about 800 feet N.W. of the slope. At this point the upper coal should be quite accessible to a shaft.

Crossing to the N.W. side of the valley, we will notice the few developments there made. These are chiefly made upon the lands of the Tinklepaugh Coal Company, who are making investigations previous to the establishment of collieries. Their lands lie upon the mountain bordering the valley on the N.W., and are S. of the notch of Tinklepaugh Creek, which passes through the property. By a series of borings, seven in number, they have established the position of the coal which they proposed to work. This is the Callender Seam. In one of the borings this seam, measuring 10 feet, including its slates, was passed through, and 7 feet beneath it, a small coal from 15 to 18 inches thick was proved. This bed is always found, though at somewhat variable distances, under the larger coal. Between 80 and 90 feet below the large coal, a bed, measuring 6 feet, is said to have been bored through. A tunnel is about being driven into the mountain from the W. side of Tinklepaugh Creek. It is estimated that the Callender Coal will be struck 300 feet from the mouth. High on the mountain, a drift enters upon coal of the following dimensions :—

	Feet.	Inches.
Coal,	5	6
Fireclay,	2	3
Coal,	3	6

Upon Dodd's Farm, high on the mountain S.W. of the Tinklepaugh Mines, several coals have been met with. Three of these, measuring respectively 2½ feet, 1 foot, and 8 inches, beginning with the lowermost, have been met with in a tunnel driven Northward 115 feet. The dip is from 25° to 30° S. Lower down on the flats, Richmond's coal-bed displays 3 feet of slate and coal. In the same neighbourhood is Callender's Mine.

On the S. side of the river, upon the lands of Samuel Ferris, in the bed of a ravine, two coal-beds have been mined to a limited extent. The upper coal is about 6 feet thick, and dips Southward very gently. In the slates beneath this coal-bed are found impressions of the beautiful fossil *Neuropteris Clarksoni* of Lesquereux. Superb specimens repose in the cabinets of Mr Clarkson of Carbondale and Mr Jones of Archbald. The lower coal dips Northward, but the drift-mouth is closed. Half a mile further Westward, Mr Hull has opened a fine bed of coal, which has been mined for use in the neighbourhood. Its subdivisions are given :—

	Feet.	Inches.
Slate and shale overlaid by mealy sandstone,	15	0
Coal,	1	0
Slate parting,	...	...
Coal,	1	6
Parting,	...	...
Coal,	1	0
Parting,	...	...
Coal,	1	6
Slate,	0	2
Coal,	2	0
Fireclay,	...	

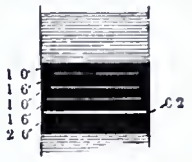


FIG. 261. — Hull's Coal, 6 miles N.E. of Scranton.

On the line of the main road to Dunmore, coal has been opened at various points, but the mines are most of them closed, and no regular series of shaftings have been made to enable us to identify the coals. Among the coals seen may be mentioned a 10-feet seam in the bank of Noble's Creek, above Dr Crandell's Sawmill, nearly under the Lackawanna Railroad crossing. It dips 10° N. Upon Mr Anderson's farm, and the farms adjoining, several coal-seams have been proved, varying from 3 feet to 7 or more feet in thickness. N.W. of Mr Anderson's house, and near the Plank Road, Mr Chittenden is now conducting the operations of a deep shaft, which is being sunk to the supposed equivalent of the Big Seam of Scranton. In the orchard W. of the shaft a coal 8 feet thick has been drifted into. A boring near by, which penetrated to a depth of 300 feet, is said to have cut a coal 2½ feet thick, 100 feet from the surface, a 5-feet coal at 115 feet, and a large seam at 300 feet. We were unable to procure the particulars of this boring. There are indications of an anticlinal and synclinal roll of the strata on the road between Chittenden Village and Mr Anderson's, upon the S. side of the river. The prolongation W. of this anticlinal would carry it a little S. of the hill at Providence. A shaft sunk by Carter near Capouse, cut a coal 6 feet thick, at a depth of 30 feet from the surface. On the W. side of the river, opposite this point, there are several old coal-openings upon a bed said to be 4 feet thick, and dipping N.

We can present no further particulars of the basin of the Lackawanna N. and N.E. of Dunmore and Providence ; enough has been said, however, to establish the fact, that the basin has been gradually deepening all the way from Carbondale, and contains a constantly increasing thickness of Coal-measures.

We now come to a systematic and careful treatment of the stratification of the basin, and of its structural features, as they are exhibited in the vicinity of Scranton.

CHAPTER III.

COAL-MEASURES OF THE SCRANTON DISTRICT OF THE LACKAWANNA BASIN.

The Seral conglomerate in the vicinity of Scranton is a coarse massive white and grey pudding-stone, consisting of two members : the lower of these, between 70 and 80 feet in thickness, is composed of coarse pebbles, of the average size of a hazel-nut, of white quartz and grey sandstone intermingled, compactly imbedded and cemented in grey and white quartzose sand, and disposed in thick and ponderous beds from 6 inches to 10 feet in depth. The upper member also, about 80 feet thick in the vicinity of Scranton, is a finer-grained and whiter rock, a quartzose pebbly coarse sandstone, alternating with dark-grey sandstones, rather than a true conglomerate. The lower of these divisions alters its dimensions in passing under the old basin, appearing on the N.W. side only 40 feet thick. The other retains its bulk, which in different localities varies from 60 to 90 feet. In certain remote districts of the basin there are indications of a thin seam of coal in the shales, sometimes parting these two members of the conglomerate, which is a sufficient fact, apart from the identity of the rock with other conglomerates included among the true Coal-measures, for ranking this great underlying stratum as a part of the true coal-formation.

It is not easy, in the present state of mining, and the development of the Lackawanna Coal-field, to estimate with exactness the aggregate thickness of the productive Coal-measures in the vicinity of Scranton, nor even to compute the precise number of useful beds of coal for every locality ; nevertheless we shall not go far astray in estimating the coal-rocks in the more central parts of the basin to have an aggregate thickness of about 500 feet, measuring from the upper limit of the conglomerate to the highest sandstones capping the table-land between the valleys of the Lackawanna and Keyser's Creek. The total number of the coal-seams included in this mass of strata is not less than *twelve*—possibly, indeed, there may be one or two more. This is without counting the subdivisions into which some of them separate in certain localities. Upon the basis of their lowest average thicknesses, the whole series constitutes a depth of coal of 59 or 60 feet ; and I am disposed to estimate the total thickness of the coal available for market, where all the strata are in the ground, at about 40 feet. It will thus be seen that the measures in this vicinity are to be regarded as uncommonly rich in coal. Eight feet of coal to the hundred feet of strata, which is a little below the true proportion here, is above the ratio found in most coal-fields. This fact, taken in connection with the prevailing low dip, approaching to horizontality, gives facility for reaching a large amount of fuel by perpendicular pits or shafts.

It is only in the higher grounds of the central portion of the basin that the uppermost coals exist at all ; elsewhere the higher measures have been removed by a greater or less depth of denudation.

THE INDIVIDUAL COAL-BEDS, AND THE STRATA WHICH SEPARATE THEM.

In describing the individual coal-beds and the strata intervening, it will be expedient to give a general account of them before entering upon the more detailed statement of their local distri-

Dalson

W. & A.K. Johnston, Edinburgh

ROARING BROOK FALLS NEAR SCRANTON

bution and character. Only those seams of coal will be enumerated which are of notable thickness and have a practical value. (See vertical column of the strata at Scranton.)

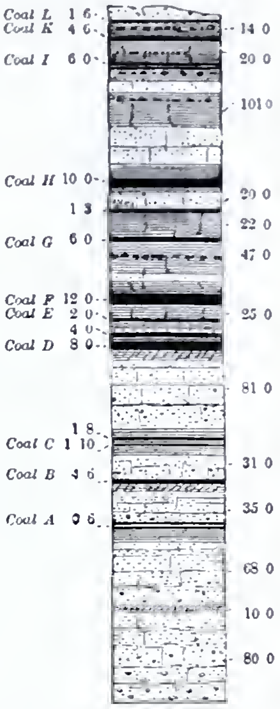


Fig. 262.—General Section of the Coal-measures at Scranton. — 1 *inch* = 200 *feet.*

Observing the ascending order, the first coal-bed which presents itself is—

Coal A.—This, the lowest coal-seam of the series, lies immediately over the upper division of the conglomerate. On the S.E. or Scranton side of the basin, it is generally a double but thin seam, the two divisions being separated by 3 or 4 feet of blue sandy shale or impure fireclay, full of the rootlets of Stigmaria. The lower layer is usually from 1 to 2 feet thick; the upper averages about 1 foot. In the immediate vicinity of Scranton this bed is nowhere suitable for mining; but at Dunmore a coal evidently corresponding to it has been mined to a small extent at Plane No. 6 of the Pennsylvania Coal Company's Railroad. It has there a thickness of about 5 feet, and dips gently N. Succeeding Coal A, which is overlaid by a thin layer of shale, there occurs a coarse conglomeritic thick-bedded sandstone, surmounted by a bed of shale; the whole is about 35 feet thick on the S. side of Roaring Brook.

Coal B.—This seam has an average thickness, in the vicinity of Scranton, of about 4 feet 6 inches. It is mined on Roaring Brook, where it displays a bottom bench 3 feet 2 inches in thickness, overlaid by 2 inches of slate, succeeded by a top bench of 14 inches of rough coal. At Plane No. 6 it is between 5 and 6 feet thick, and is successfully mined. Under this coal is a bed of fireclay 5 feet thick, containing rootlets of Stigmaria.

Immediately upon Coal B reposes a thin-bedded micaceous sandstone, obliquely laminated; and upon this about 11 feet of coarse Stigmaria shale, succeeded by fireclay, which constitutes the floor of the next coal; the whole interval between Coal B and this latter being about 31 feet.

Coal C consists of two benches, the lower 17 inches, the upper 22 inches thick. At Dunmore, where it has been mined to some extent in the hill supporting Plane 6, its total thickness is nearly 5 feet. At Spencer's Mine it contains 4½ feet of good coal. On Roaring Brook the two divisions of the bed are separated by 6 feet of Stigmaria shale.

Directly overlying the roof-slate of Coal C is a mass of thick-bedded obliquely-laminated sandstone, in all about 70 feet thick, and upon this about 12 feet of shale, the upper 3 feet of which is fireclay, imbedding the usual Stigmaria rootlets. These intervening measures have a total thickness of 80 or 82 feet.

Coal D.—On Roaring Brook this is generally a double seam, the lower bench measuring from 6 to 7 feet, the upper, sometimes called the Four-feet Seam, varying from 1 to 6 feet.

On the N.W. side of the basin, in the vicinity of Legget's Gap, it has been opened at several points.

Clark's Mines are dependent upon this coal-bed, and the New York and Pennsylvania Coal Company are about to work it from a tunnel driven back from their slope on the Big Coal (F) above it.

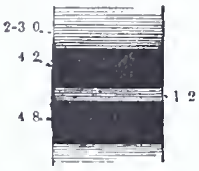


FIG. 263.—Coal F (Big Bed), New York and Pennsylvania Company's Slope Mine.

Capping Coal D is a sandy micaceous shale 5 feet thick, succeeded by 10 feet of rough fireclay, imbedding large globular masses of clay iron-ore, or argillaceous carbonate of iron. The nodular masses of the ore are generally 2 or 3 feet in diameter, distributed in one layer, sometimes nearly in contact, but more usually 2 or 3 yards asunder. The interval between D and E is on Roaring Brook from 12 to 15 feet.

Coal E.—The next coal in the series seems to be of variable dimensions. On Roaring Brook its thickness is about 20 inches; but at the Lackawanna River, a little W. of the Bellevue Mines, a bed occupying the position next beneath the great seam F, has a far greater size, containing, indeed, some 8 feet of coal of different qualities.

Resting upon Coal E, and constituting the floor of the next superior bed, called from its large size the Big Coal, there is interposed on Roaring Brook a bed of black slate, shale, and micaceous shaly sandstone, varying in thickness from 7 to 12 feet.

Coal F.—This large and valuable bed of coal, measuring in the different localities around Scranton, where it has been cut, from 11 to 14 feet, and even 18 feet, is not a simple seam, but usually consists of two or three or more benches. On Roaring Brook, where the seam has its most South-eastern outcrops, its thickness is about 13 feet, and this appears to be about its size in the boring carried down from the bottom of Shaft No. 2 at the Diamond Mines. It is of like dimensions at the Pinebrook Mines, but further S. on the river it is considerably thicker, being 18 feet in depth, including its parting-slates. The details concerning this coal will be presented hereafter.

Interposed between the Big Coal F and the next succeeding seam there occur from 55 to 60 feet of strata, consisting, first, of a sandstone resting on the roof-slate of F, then a considerable thickness of sandy slate and shale, then a thin laminated sandstone, and above this shale or impure fireclay, forming the floor of the coal-seam G. At the Diamond Mines in Shaft No. 2, this interval measures about 43 feet, and in a boring in the Diamond Mine-drift 47 feet; but in an old boring near the Bellevue Mines, where the measures appear to be very different, the interval amounts to nearly 97 feet, the materials, so far as we can rely upon the indications of the chisel, consisting of sandstones in the upper half, and for the most part of slate and shale in the lower.

Coal G (or the Seventh Coal) rests upon shale, and is sometimes overlaid by slate, and sometimes by micaceous sandstone. Like most coals which consist of two or three or more benches, it is somewhat inconstant in its thickness, varying from 6 feet as a minimum to 10 feet or more as a maximum, counting the included layers of slate. It appears to possess an average workable thickness of 6 feet on the N.W. side of the river. Its total thickness at the Diamond Mine-shaft is 9 feet 5 inches, of which 7 feet 4 inches represent good coal. Its subdivisions will be given presently.

Between the last-named coal and the next, designated as H by us, though at Scranton it is usually called the "Diamond Coal," from the brightness of the lustre of one of its large benches, there is usually interposed a body of slate and sandstone, apparently of quite variable dimensions. At the Diamond Shaft the whole interval seems to amount to no more than about 10 feet, which is occupied by a sandy slate; but in the boring from the Diamond Mine-drift the space is reported to be $43\frac{1}{2}$ feet, its lower half being filled by sandy slate, and its upper half by sandstone. In the ravine near the Bellevue Mine, the space there separating the two coals, considered as the equivalents of G and H, measures by estimation about 35 feet. We are disposed to attribute the narrowness of the space between these coals at the shaft to a dislocation of the strata, of which there are some evidences in the ravine near by.

In the boring at the Diamond Drift, a coal, one foot thick, seems to have been cut midway between G and H.

Coal H.—The Diamond Seam reposes on a thick bed of clay-shale, or impure fireclay, containing rootlets of Stigmaria, and covered by a roof of a more sandy variety of the same rock, filled with beautifully-preserved ferns and other fossils. This bed of coal is sometimes called the "Ten-feet Seam." Like most of the others, it is a compound bed, though its principal bench, the uppermost, is generally a very thick one. In Shaft No. 2, the whole bed measures 12 feet 3 inches, and contains nearly 11 feet of coal. In a boring near the Vanstork Mines it indicates a thickness of more than 11 feet. In the Washburn Mine the whole thickness is 9 feet 9 inches, one foot of this being slate; and in the Fellows Mine, if our identification is correct, its whole size is only 7 feet. It would thus appear to decline in thickness as we trace it from N. to S., a view which is confirmed by the fact that the coal in the ravine on the Griffin Farm, regarded as the Diamond Seam, measures only 6½ feet, embracing 4 feet of coal.

Between Coal H, or the Diamond Seam, and the next higher one, sometimes called the "Seven-feet Bed," there is usually an interval of from 60 to 100 feet. This is occupied chiefly by sandy slates and argillaceous sandstones, with some beds of genuine quartzose sandstone. Near the central portion of the interval occur one or more layers of ball iron-ore, or nodular argillaceous carbonate of iron, imbedded in soft shale or fireclay. These layers have been met with in Shaft No. 2, and also in a boring near the same shaft; again in a boring on Washburn's land, S. of Keyser's Creek, near where the Hyde Park Company are operating; and in a boring near the Vanstork Mines, W. of Providence. Other layers of the ball iron-ore occasionally appear in the black slate which next overlies Coal H, as may be seen in Shaft No. 2. At the Diamond Mines the whole interval measures about 100 feet; on the fuller lands, much further N., the space amounts to no more than 66 feet, and it is considerably less than 3 feet in the ravine of the Griffin Farm, if we are correct in our identification of the coals there.

Coal I.—This coal, next above the Diamond bed, formerly known as the "Seven-feet Seam," and wrought a few years ago in some drifts above the Diamond Mine, is not at present mined in the vicinity of Scranton. The size of the bed can be best estimated from exposures in the ravine near Lewis and Howell's Slope-mine. At these openings it exhibits a thickness of 5 feet in two benches, displaying coal of good quality.

Succeeding Coal I, and separating it from the overlying seam, which we have called K, formerly known as the "Five-feet Seam," we meet with a stratum of soft ferruginous shale, and in some localities shale and sandstone. Along the S. face of the table-land, on which is seated the village of Hyde Park, the two coals range close together, the interval amounting to no more than about 20 feet. Further Southward on the Griffin Farm, the space between Coals I and K is very much greater—so much so as to justify some doubts as to the correctness of our identification, but it must be borne in mind that, as the upper coals of the basin are much less continuous than the lower ones, from being restricted to the higher hills and table-lands, between which wide spaces of the measures have been cut away, they are much less easily identified from point to point; and in their present undeveloped condition, mining operations having not yet extended to them, their relationships remain very obscure.

Coal K.—This bed of coal, best developed in the ravine near Lewis and Howell's Mine and along the Hyde Park Bluff, has a thickness of about 4½ feet. It is not at present mined near Scranton, but may at a future day prove valuable in localities where it possesses sufficient covering.

Coal L.—At an interval of about 12 feet above the Coal-bed K is a thinner seam, which at the above-mentioned ravine and in Hyde Park Bluff measures 1½ feet in thickness. At the head of the Griffin Ravine, near the Pittston Turnpike, the bed, which we have regarded as the equivalent of this, measures as much as 5 feet of good coal in two benches, being thicker than Coal K, from which it is separated by about 27 feet of blue slate, this underlying coal being at this locality scarcely 3 feet in thickness.

Along the Hyde Park Bluff, the interval of 12 feet between Coals K and L consists in the lower 5 feet of soft clay-shale, and in the upper 7 of blue sandy shale and slate, sometimes running into fireclay, with balls of rather coarse nodular iron-ore.

UNDULATIONS OF THE STRATA IN THE SCRANTON DISTRICT OF THE LACKAWANNA COAL-BASIN, AND THE DISTRIBUTION OF THE SEVERAL COAL-SEAMS IN THEIR LOCAL BASINS.

The several flexures which gently undulate the coal-beds of the district around Scranton, and which exercise a controlling influence on the distribution of the coal-seams, and the mining operations connected with them, are ten in number. We shall begin our description with the most Southern. Only the most prominent are inserted on the Map.

Anticlinal Axis No. 1.—The first notable axis lifting the rocks in the Southern part of the field near Scranton, is one which may be traceable from the stone quarry on the S. side of Roaring Brook, in a direction S. 70° W. across Stafford Meadow Brook, and finally across the back road to Pittston, where it is marked by a decidedly S. dip, at a point about half a mile W. of that stream. It appears to prolong itself as a very gentle undulation to the lower Swetland Coal-openings. Throughout its course the wave is very flat.

The coals lifted to the surface along this saddle or arch are evidently the lowest in the whole series—indeed, at Roaring Brook it is in the conglomerate, and outside of the coal altogether; but, proceeding Westward, it enters the areas of Coals A and B, and perhaps C, making a very shallow sloping basin of these with the Northerly-dipping strata of the conglomerate, which stretch Southward over the slanting plateau towards Stafford Meadow. A little to the S. of this anticlinal, two coal-beds have been opened in the basin in question, in the ravine of a little stream near the Smith Tract. The opening nearest the axis displays a bed 9 feet thick, dipping S. 2°; the other opening, further to the S., shows a coal 5 feet thick, dipping in the opposite direction, or Northward. Whether these belong to the same coal has not been ascertained, but they evidently embrace between them the middle of a shallow basin.

About 800 feet to the S. of the anticlinal, here called Axis No. 1, there are indications of another gentle wave ranging parallel with it to the back road. It may to some extent affect the mining at the collieries recently established near the township line. Both this and the main axis, No. 1, evidently rise towards the E.

Anticlinal Axis No. 2.—This, the first really conspicuous flexure of the district, is a long and very important one. It commences in the Dunmore Ridge, of which it is the most conspicuous undulation, being there discernible in very gentle S. dips in the hill S. of the village, between it and the mines. It is thought to cross the Drinker Turnpike about 1000 feet S. of the Lackawanna Railroad crossing. We detect it again on the South road leading from the mines to the main Scranton Road, from which point we may trace it to the Odd Fellows' Hall at Scranton, the axis following the West-sinking crest of the ridge. Two or three subordinate gentle undulations occur on the flanks of this wave between Dunmore and Scranton. This anticlinal is strikingly exhibited in the lower ridge of the Odd Fellows' Hall, where its S. dips are quite gentle, not exceeding 5° or 8°, whilst its N. ones are at 45° or even 60°, making the steep rocky bluff bordering Bank Street of the borough of Scranton. Traced Westward, it pursues a remarkably straight course about S. 75° W. to the Lackawanna, the flat ground of which it crosses S. of the covered bridge, entering the bluff bank overlooking the river at the mouth of Roaring Brook. It next displays itself in the cutting on the Lackawanna and Bloomsburg Railroad, N.E. of the Bellevue Mines. In the S. dips in this cut there are some indications of a downthrow, by which the very obliquely-bedded sandstones of the centre of the arch appear to be replaced by arenaceous slates. The plane of the fault dips Eastward at an angle of 70°, but its extent has not been determined. Pursuing the anticlinal axis Westward, it becomes more obscure, partly on account of its growing flatter, partly because of the obliquity in the bedding of the strata making the direction of the true dip uncertain. Expanding into an extremely gentle N. and S. dip, it ranges through the high ground which supports Mr Sherrard's house, and passes into the high table-land between the Lackawanna River and the valley of Keyser's Creek.

In this comparatively long range the flexure is arched by all the coal-seams in succession, from the very lowest of the series in the Dunmore Hill to the highest occupying the table-land N. of the Lackawanna. The details will be presented after the several anticlinal waves have been traced.

Anticlinal Axis No. 3.—The third flexure of the group is nowhere very distinctly exposed in any surface developments, but it is met with in the Pinebrook Mines, Nos. 2 and 3, where the coal is very gently arched by it, and the gangways of the mines are in consequence inflected. The crest of the arch passes near the air-shaft of Dip No. 3, or that of the slope. Westward of this its existence seems to be proved by a slight flexure of the coal in the old gangway of Washburn's Mine, but nowhere else has it been detected as a distinct roll.

Anticlinal Axis No. 4.—A far more important anticlinal wave lies a few hundred feet to the N. of the preceding one, pursuing a direction very nearly parallel with it and those previously described. It is displayed in the sandbank drift, or No. 1 of the Pinebrook Mines, where it shows both its N. and S. dips. It has not been discovered Eastward, but Westward its next distinct exposure is in the low broad arch at the Lackawanna River, near Washburn's Mine, where a coal, which appears to be the Diamond Seam, is lifted by it to the surface. From the circumstance that it lifts Coal F, or the Big Seam, high above the river-level at the Pinebrook Mine, while at the bend of the river at Washburn's it barely brings above the water-level Coal H on the back of the arch, it is obvious that this axis declines at a sensible rate to the Westward. Therefore it is, that, entering the high ground W. of the river, it is saddled by the upper coals of the series. The cuttings of the Bloomsburg Railroad have exposed this arch to view in a succession of obliquely-bedded coarse micaceous sandstones of the ordinary type. On the Pittston Turnpike it is not distinctly indicated except in a few rather variable flat dips. If prolonged thus far, it would pass through the high lands in the central part of the Griffin Farm.

Its position Eastward seems to be indicated in one of the swells of the ground on the N. brow of the Dunmore Hill.

Anticlinal Axis No. 5.—At a distance of some 1500 feet N. of the preceding axis, there exists another anticlinal of some importance, the first which as far E. as Scranton lies altogether N. of the river. Owing to the general covering of diluvium in the immediate valley of the Lackawanna, this flexure does not show itself at the surface until it enters the hill just N. of the river, where the Fellows' drift-mine is situated in the Diamond Coal. There it elevates both coals G and H above the water-level, throwing them into N. and S. dips. Thence it is traceable Westward under the escarpment of the table-land occupied by the village of Hyde Park. Under this bluff it imparts to the coals K and L, which are there opened, a perceptible N. dip. On Washburn's Land the flexure may be detected in a little ravine, where it brings Coal K, and the small seam above it, Coal L, to the surface near the drift formerly called Phillip's. From this point it probably ranges near Fellows' Corner, and seems to cause the N. dip in the sandstones which are slightly exposed near the lime-tree standing in the cross-road which forms the E. boundary of the Griffin Farm from the Pittston Turnpike to Keyser's Creek, near Courson's Hampdon Mines. Beyond this spot all certain indications of it are lost, but its course is sufficiently well determined to enable us to affirm that it will traverse the N. slope of the high ground through the Griffin and the neighbouring farms. This flexure evidently sinks gently Westward, and dies away in that direction, but at a less perceptible inclination than some of those previously traced.

Anticlinal Axes Nos. 6, 7, *and* 8.—We come now to a group of three small undulations which occupy the general basin of the Diamond Coal. The first or Southern of these, No. 6, makes its appearance a few hundred feet S. of Lewis and Howell's Slope, on the railroad, in a confusion of dips, the prevailing ones indicating a flat arch. It has nowhere been observed except at this point, where it affected the progress of the old Swetland Mine by causing N. dips.

Of the two other undulations, one is visible in the bed of the ravine near the slope above mentioned, where it barely inflects the strata ; the other exhibits itself as a slight undulation of the coal in the Diamond Mines. These two latter flexures, like the first named, have hitherto been seen only at the points now referred to.

Anticlinal Axis No. 9.—In the progress of mining in the Diamond Drift, a roll or abrupt undulation was met with, which for some time arrested its extension. This was a rather sudden turn in the dip of the coals, which altered its prevailing Southern inclination of 5° or less into a comparatively steep N. one of 15° or 20°. Though called a "fault" by the miners, it is really not such, but simply a saddling of the coal underground. The coal has been worked down the N. dip. The course of the anticlinal axis appears to be about S. 70° W. This takes it through a point a few feet N. of the air-stack in the field to the W. of the turnpike road. Westward of this spot, surface indications of its presence are wanting, and mining has not brought it to light.

Anticlinal Axis No. 10 (?)—Of the structure of the coal-field N. of the last-described axis of the Diamond Mines, very little is at present known, nor is much definitely ascertainable until the mining is more extensively prosecuted in that quarter. There are, however, indications of a saddle in one of the cuttings of the railroad, which, if prolonged, would range about 1000 feet N. of the flexure last described. The topographical features of the ground appear to sustain this view, being such as a broad roll would impress.

The character of the ground, from the parallel of the last-mentioned axes to Keyser's Creek, is such as to obscure every indication of its structural features, and on the N. side of the stream the plain is deeply covered with drift as far as the rising slope of the mountain, which effectually obscures the coal strata.

We have no evidence of any anticlinal rolls on the flank of the mountain, though they will doubtless be discovered in the progress of research.

The conglomerate on the N. side of the valley, though in many places it exists only in detached masses, is elsewhere visible in conspicuous ledges. Its position is generally within the township line, a variable distance of from 500 to 1000 feet. The limit of the productive coal-field will probably be as much as 2000 feet within the line. As the conglomerate approaches Legget's Gap, it forms a separate inner ridge to the main mountain, and dips rapidly down into the gap. One or two unimportant beds of coal have been cut closely over it in the gap near the railroad.

Positions and Distribution of the several Coal-seams.—In explaining the positions occupied by the several beds of coal, and tracing them as they are distributed around Scranton, it will be convenient to indicate them first as they are lifted to the surface in succession along the several anticlinals, and secondly, as they outcrop one above another in the troughs or basins embraced between those saddles. Observing the order previously adopted in tracing the anticlinals themselves, we will commence with the coals brought to view along the crest of the first principal flexure—namely, Axis No. 2, or that which ranges from the Dunmore Hill, through the ridge of the Odd Fellows' Hall. It has been already intimated that the three lowest coals of the series, or Coals A, B, and C, lie high on both slopes of the Dunmore Hill; and it may be added, that to the E. of the village A must spread itself over a considerable area on the very flat rising back of this broad elevated saddle. Descending W., these coals wrap round the base of the hill with a curving outcrop, changing their dips from N.W. to S.W. as they sweep round to take their places, one above the other, in the basin of Roaring Brook, at Plane No. 6 of the Pennsylvania Company's Railroad. In ranging through the ridge of the Odd Fellows' Hall, this gradually subsiding saddle just permits the Coal D to arch over it near the Hall with a gentle S. and a steep N. dip. Further W., at the junction of Roaring Brook with the Lackawanna, the strata which it brings to the surface are the higher ones, apparently those between the Big Coal F and that we have called G. It is probable that the Coal G, to the W. of this angle of the river, unites its two outcrops as the ground rises and the axis sinks; and that to the W. of the mining village, the drift there opening a coal having a very gentle S. dip, belongs to the still higher Coal L, or that which is exposed near the head of the Griffin Ravine, close to the Pittston Turnpike Road.

Coals in the Basin South of Axis No. 2.—Sketching the coals in the basin S. of the second main axis, we find in the Southern escarped face of the Dunmore Ridge at Spencer's Mines (worked by Stevenson), four coal-beds above the conglomerate. Of these the third coal, C, of our enumeration is successfully mined. The centre of the basin is thought to be about 150 feet N. of the mine mouth, the lowest of all outcrops a few feet below the level of Roaring Brook, near the foot of Plane No. 6. A mile and a half to the W., the second of these beds, or Coal B, crosses the gorge of the stream a few hundred feet S. of the Rolling Mills with a slightly N. dip. The two next higher principal seams, D and F, or the Big Coal, basin near the Furnace Dam, their S. outcrops passing the stream below the Rolling Mills, and their N. ones just rising to Anticlinal Axis No. 2, near the Odd Fellows' Hall. They basin out to the E. several hundred yards above the Furnace Dam. Below the Grist Mill, Coal G, sometimes called the Six-feet Bed, shows its S. outcrop near the back road, on the edge of South Scranton, or the working people's village. This coal, as already intimated, has its N. outcrop in this basin, a little S. of the junction of Roaring Brook with the Lackawanna. On the W. or rather the N.W. side of the last-named stream, we meet in this basin with all the coals from D, E, and F, near the margin of the river, to Coal L at the Griffin Ravine. Of the distribution of these, some details will presently be given.

The Southern limit of the subordinate coal-basin which we have now been tracing, is well defined by the outcropping of the massive beds of the underlying conglomerate whose pebbles are of nut and even egg size. This rock flanks the mountain at Plane No. 7, also on the S. side of Roaring Brook, opposite Spencer's Mines. It forms precipitate ledges at the falls of Roaring Brook, and extends along that stream to where it turns to flow N.W. Thence it sheets the flank of the mountain, along which run the two tracks of the Pennsylvania Coal Company, and it displays itself upon the rocky bluff faces of the mountain on both sides of Stafford Meadow Brook, following which it sweeps round to occupy the back valley of the Ore Mines. There is an inner ridge between the deep gorge of Roaring Brook and that of Stafford Meadow. The S. side of this is steeply escarped, as shown in our profile Section. The high watershed above this steep slope is capped by the coarse grey and somewhat pebbly sandstone which underlies Coal B or the Four-feet Seam. Under the ledge formed by this hard rock we may trace the thin seam A, and the thin upper layer which accompanies it, and may detect the Stigmaria shale which invariably attends them.

Coal B in Roaring Brook Basin.—From the point at which this bed is worked near Plane No. 6, its outcrop ranges along the slope of the hill which overlooks from the N. side the valley of Roaring Brook. It holds its assigned place under one or two conspicuous ledges of solid sandstone. Sweeping gradually round in a line approximately parallel to the stream, it crosses the railroad in the first cut above the Rolling Mill, where it is finely exposed. From this place it dips to the Rolling Mill-dam, immediately below which, at the end of the mill, a tunnel is driven to cut the coal. On the opposite side of the stream, the coal, rising from the water-level at an inclination of about 10°, is entered by a drift, now furnishing coal to the furnaces. From this point the outcrop of this bed, traced W., lies high on the inner ridge, running nearly parallel to its escarped face. It then gradually deflects more rapidly W. to the valley of Stafford Meadow Brook, beyond which its outcrop has not been followed. This coal is not known to outcrop anywhere else, except as here described, in the Scranton district, until, on the opposite side of the general basin, it rises to the surface again high on the slope of the mountain bounding the valley on the N.W.

As this Coal B presents itself in the mine on the S.W. side of Roaring Brook, it consists, as already said, of a bottom bench 3 feet 2 inches thick ; over this a layer of slate 2 inches, and above this 14 inches more of a roughish coal. At Plane No. 6 it measures between 5 and 6 feet. Its productive thickness is about 4 feet.

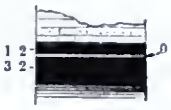


Fig. 264.—Coal B, Roaring Brook.

Coal D, in Roaring Brook Basin.—The next workable seam in this first subordinate basin, or that of Roaring Brook, makes its appearance near the falls of Roaring Brook in an outcrop about 1500 feet N.W. of the N.W. crop of Coal B last traced. Following this W., it curves gently N., to take a position in the ravine where an opening on Mr Sanderson's land was designed to enter it. Beyond this point it pursues a direction almost due W., and skirting the Southerly face of the hill on which Mr Selden Scranton's house is situated, it dips at a gentle angle to the Furnace Dam, where two drifts enter it at different levels, penetrating far under the hill. On the S. side of the brook it is not mined, but its outcrop can be traced in an almost straight line towards Mr Slocum's house near Stafford Meadow Brook. This is doubtless the same seam which is exposed at the river bank a little beyond the Bellevue Mines. It is represented in our Section of the coals at that point where it is shown to be subdivided by bands of slate. In the inner workings of the drifts on Roaring Brook, this coal is squeezed out by the approach of the upper and lower rocks. Its dimensions, where this thinning-away in the upper level commences, are as follow :—

	Feet.	Inches.
Coal,	4	6
Slate,	0	5
Bony coal,	0	9
Coal, good,	1	0

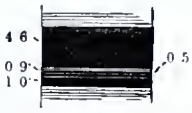


Fig. 265.—Coal D, Scranton, near the Rolling Mills.

About 50 feet further forward the upper bed thins down to 2 feet, and is gradually lost. How far this pinch continues was not ascertained at the date of our last examination (1856). The so-called "Four-feet Seam" overlying it, varying from 1 to 6 feet in thickness, is in many places worked in the same mine with this.

Coal E, Roaring Brook Basin.—Nothing additional to what has been already stated respecting this thin seam need be here given, further than to call attention to the fact that this coal, if it ranges to the bluff back of the Lackawanna W. of the Griffin Farm, is there most probably either a lower bench of the Big Coal E, or an upper division of the next main lower bed D.

Coal F, Roaring Brook Basin.—The large seam, Coal F, has been more exposed to removal by excavating floods than either of those previously described, simply from its higher position in the series. It is evidently wanting in the high ground near the village of Dunmore, nor have we any evidence of its presence until we approach the flats on the road leading from Dunmore to Providence. It would seem to have escaped denudation on the S. side of the saddle of the Odd Fellows' Hall (Axis No. 2) all the way W. from a point a little E. of Mr Joseph Scranton's residence. Followed E. from this spot, its outcrop passes a little S. of Mr Mati's house. Before reaching the Falls Road, it swings round to run parallel with it for about 100 yards, and there deflects rapidly to take the brow of the hill, along which it ranges parallel to Coal D, until it is cut by the valley of Roaring Brook ; then it swings with the stream toward the furnaces, in digging the foundations for which it has been cut near the creek-level. It thus appears that the hill supporting Mr Selden Scranton's house occupies nearly the centre of the basin of this coal-bed. This valuable seam, in consequence of its very gentle dip, presents a long line of frontage to the stream opposite the furnaces, where, for several years past, it has been mined. Traced W., its outcrop may be seen from the character of the surface to approach that of Coal D, but it soon becomes obscured by a deep covering of diluvium. Further W. in this basin, the Big Coal ranges under the flats of the Lackawanna until it emerges once again to view at the foot of the river bluff. There it gives indication of a feeble undulation in an old drift, but this flexure is nowhere discoverable further E.

OF THE ROARING BROOK BASIN WEST OF THE LACKAWANNA.

Crossing now the Lackawanna, and studying the strata, with their coal-beds, as they are developed by surface-proving and mining on the Griffin Farm and mines adjoining, between that stream and the Pittston Road, we find the ground to contain, in the line of the Roaring Brook Basin, the whole succession of the coal series of the district, from Coal D at the edge of the river to Coal K, near the head of the ravine at the road. This sequence of the coal-beds, with their included strata of shales, slates, and sandstones, is represented in a profile Section under their true dips and relative thickness.

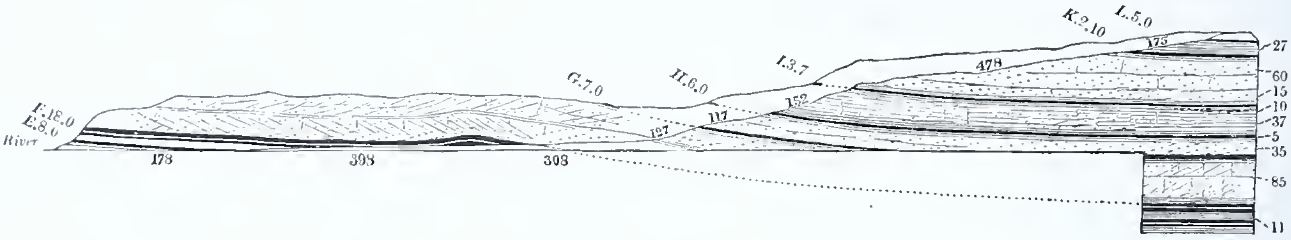


FIG. 266.—Section of Griffin Ravine W. of Scranton, looking N.E.—1 *inch* = 400 *feet*.

This Section spans two-thirds of the breadth of the Roaring Brook Basin, the other third extending from the Lackawanna to the anticlinal axis No. 1, or that which lifts one of the lower coal-seams to view a little S. of the back road to Pittston. It will be observed, however, from the Section, that there prevails but one direction of dip in the strata across this broad space. This is in consequence of the flattening down of the second anticlinal, the arching of which is barely noticeable at the mouth of Roaring Brook, and becomes almost or altogether null as far W. as the main road, its sole effect there being to lift the strata into a horizontal position, not to incline them S. The coals do not lie, therefore, strictly in basin form, but only on the S. side of a very broad flat basin, the one margin of which is the S. Axis No. 1, the middle of which is the high table-land between the Lackawanna and Keyser's Creek, gently undulated perhaps by one or two of the anticlinals of the Lackawanna; and the N. side of which is formed by the South-dipping strata of Keyser's Creek on the mountain N. of it. As already intimated, only the lower coals have their outcrops S. of the Lackawanna opposite the Bellevue Mines, but as we go further S.W., near the township line, coals even as high as the Diamond Seam appear to come in. On the lands of the several companies entitled the National, the Quaker City, and the Anthracite, collieries have been recently established on one or other of these coals, but particularly on coals D and F. At Taylorsville, upon the Union Coal Company's property, extensive shaft-mines have been commenced upon coals thought to be D, F, and G. In the bluff which ranges from the river on its N. side to the mouth of the Griffin Ravine, coals D, E, and F appear, and it is obvious, from the direction of their dip and the form of the ground, that their outcrops, under the alluvial flat below the Bellevue Mines, must, from the depth to which the coal strata have been there washed away, lie considerably to the N.W. of the lines prolonged from their outcrops at the foot of the bluff; in other words, a deep denudation has swung their outcrops Northward.

Following this bluff, and afterwards the Griffin Ravine, into which it prolongs itself, we meet with the several coals in succession thus: First, close to the river edge, at the base of the hill, appears *Coal D,* dipping very gently Northward from the stream. Its face has been well stripped to show its quality, size, and subdivisions, which are as follow:—

	Feet.	In.		Feet.	In.
Coal, very good, . .	4	0	Slate, ...	1	0
Coal, bony, . . .	0	11	Coal, good, . . .	1	8
Slate, ...	0	8	Slate, ...	3	6
Coal, ...	1	0	Coal, ...	1	4

Coal E of Roaring Brook has, at this more Western locality, either thinned down and disappeared altogether, or it has merged itself into Coal F as a lower bench, by the thinning-out of its few feet of overlying fireclay, the most probable view of the two.

Coal F.—Regarding the second thick mass of coal as one seam, though made up of several benches, and viewing it as the equivalent of the Big Seam of Roaring Brook, we find it developed in usual magnitude in the bluff at the river. Its dip is extremely gentle Northward, and several drifts and provings give ample opportunity for estimating its size and subdivisions; these are as follow:—

	Feet	In.		Feet.	In.
Coal, . . .	1	0	Slate, . . .	0	6
Slate, . . .	0	6	Coal, . . .	0	7
Coal, bony, . .	1	3	Slate, . . .	0	2
Coal, . . .	5	0	Coal, . . .	2	4
Coal, bony, . .	0	4	Slate, . . .	0	6
Slate, . . .	1	6	Coal, . . .	2	9
Coal, . . .	2	0			

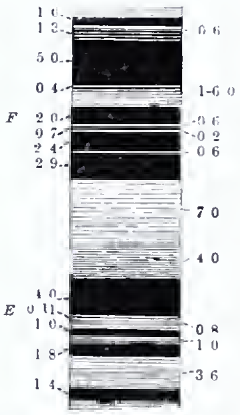


FIG. 267.—Coals F (Big) and E, River Bluff, near the Bellevue Mines.

This coal vanishes under the flats a few hundred feet S. of the mouth of the Griffin Ravine, and must outcrop in the flats S. of the Bellevue Mines.

The next seam ascending is *Coal G.* This enters the ground above the water-level of the Griffin Ravine immediately N.W. of the Lackawanna and Bloomsbury Railroad; its outcrop curving Eastward out of the ravine, and thence N.E., passing S. of the slope, and N. of the Shaft No. 1 of the Bellevue mines. The coal having been washed away at the point where the shaft is sunk, the coal-bed first to be met with in this shaft will be the Big Seam. The depth reached in January 1856 was 120 feet, making it probable that the large coal would soon be struck. This coal-bed of the slope, or G, exhibits at this locality—

	Feet.	Inches.
Coal, ...	2	6
Slate, ...	0	2—4
Coal, ...	3	6

The slope does not enter directly upon the coal, but reaches it through overlying material at a moderate depth, by descending at a steeper angle.

The coal next above that entered by the slopes is also exposed in the Griffin Ravine west of the Bellevue Mines, where its outcrop is about 35 feet above the slope-bed. In geological position it corresponds to the Diamond Seam, though at this locality it fails to sustain the usually high reputation of that coal. It contains between top and bottom slates a thickness of 6½ feet, though at this point the good coal amounts to only 4 feet. It seems to underlie the high ground back to Keyser's Creek, near which stream, at the Hampton Mines, a shaft has been sunk, meeting what appears to be this coal at a depth of 121 feet beneath the surface. The seam there struck possesses the usual dimensions and good quality of the Diamond bed. At that shaft the following measurement of the coal was obtained :—

	Feet.	In.		Feet.	In.
Coal, . . .	5	9	Slate, . . .	1	10
Coal, bony, . . .	1	3	Coal, . . .	1	8
Coal, fair quality, . .	1	10	Fireclay, . . .	...	

The dip is 2° S., from 10° to 15° E.

A little East of the Hampton Mines, the Hyde Park Coal Company propose working the same bed by a shaft, which it is estimated will require to be sunk about 115 or 120 feet from the surface.

In the Griffin Ravine, as shown upon the Section, the next overlying coal-seam lies about 52 feet higher than the previous one, though, from some dislocation or slip near the Bellevue Slope, the interval which there separates them is only a few feet. Where visible, this coal has a thickness of about 3½ feet.

The next ascending, considered to be Coal K, is separated from that last mentioned by as much as 80 feet of argillaceous sandstone in the Griffin Ravine. It is about 3 feet thick.

The highest coal, L, here discovered displays, in a trial-shaft made at the head of the ravine near the turnpike, a thickness of 5 feet of good coal. It evidently is to be found only in the higher ground. This upper coal is that formerly opened on the old road leading to Landis's house on the turnpike. At this point the dip is 2° S., showing it to be on the N. side of the basin. It is supposed to be the same coal which is worked in the depression further towards Hyde Park known as Philips' bed.

On the top of the saddle, No. 2, exposed in the cut Eastward from the Bellevue Mines, the seams above Coal G appear to be denuded away, to enter again under the higher ground further W. In this cut of the railroad a boring is reported to have met with the following results : Rock, 16 feet ; slate, 1 foot 4 inches ; coal, 7 feet 8 inches, divided by 7 inches slate ; slate feet to rock. The coal here cut is deemed to be the slope-coal G. Along the top of the cut, black dirt is visible, and the same was cut in several wells. This may be "washing" from the Diamond seam.

Coals on Axis No. 4.—It has been already intimated that the anticlinal axis or saddle No. 4 elevates the Big Coal F to a considerable height above the Lackawanna, in the Pinebrook Mines, without lifting it out to the surface. Between the water-level workings of this mine, and the bend of the Lackawanna River below the bridge uniting Scranton with Hyde Park, Coal G must somewhere span this saddle, dipping Northward into the synclinal basin occupied by the river, and Southward into the narrower and flatter basin contained between this and Axis No. 3. It is probable that the N. and S. outcrops of Coal G meet on the back of the saddle somewhere near the Freight Depot, though they are entirely concealed by drift. The next coal which arches the axis is that of Washburn's Mine at the bend of the Lackawanna, which, there is every reason to believe, is the Diamond Seam, or Coal H. Of course, if the anticlinal continues gradually to sink and flatten in proceeding Westward, the mining in this seam cannot be carried far in that direction before the coal will lap across the axis and sink to the water-level. Ascending towards the main road along the line of this axis, we find it nearly spanned by one of the upper coals, apparently K, or the so-called "Five-feet Seam," at this road between the old Philips Drift and the Griffin Farmhouse. Beyond this vicinity the axis and the coals upon it cannot be traced.

COALS IN THE SCRANTON BASIN, OR THAT BETWEEN AXIS NO. 2 AND AXIS NO. 4.

The most accessible or highest workable coal embraced between the limits of the Odd Fellows' Hall anticlinal and that of the Washburn Arch, is the Big Seam, or Coal F. The mine-galleries or gangways in this coal enable us to trace its outcrop with considerable precision. Commencing with the S. brow of the hill N.E. of the Rolling Mill, overlooking the depression in which Coal D is opened, the outcrop of the Big Seam is traceable Westward to the Falls Road, which it barely crosses, turning almost immediately N. to run parallel to the road, which it presently recrosses to saddle the anticlinal axis of Dunmore and the Odd Fellows' Hall, passing under Mr Hitchcock's barn. On entering the main Scranton Basin it crosses the Dunmore and Scranton Road at right angles, a little E. of where the Falls Road turns off. The outcrop now swings away towards the centre of the town, and is no longer traceable. The subordinate anticlinal, No. 3 of the series, which passes through the centre of the town, throws out the Big Seam to the surface S.E. of Pinebrook, and the coal is exposed in two lines of outcrop which converge Westward, and unite across the saddle near the air-shaft connected with Drift No. 3. The Southern outcrop connected with this saddle crosses Olive Street of Scranton almost at right angles, then bends and runs parallel to it, and finally sweeps round and becomes parallel to its first course, when it again turns and crosses Madison Avenue. The Northern line of outcrop pursues a nearly Easterly course from their point of divergence over the axis. Drift No. 3 enters by a slope until it strikes the coal dipping N., then swings round Southward over the saddle, meeting Drift No. 2, which enters nearly S. of the saddle further Eastward, being driven to meet the coal on its S. dip. It was stated that the other axis next N., or No. 4, does not lift the Big Seam to the surface, but is surmounted by the gangways in the Pinebrook Mine No. 1. A deep covering of diluvium hides all the strata between the Pinebrook Mines and the river at Washburn's Mine. Even the wells, sunk in the sand and gravel to a depth of 70 feet, have failed to reach the Coal-measures.

The following are the subdivisions of the coal at the Pinebrook Mine No. 1. It may be taken as a type of the coal at the various openings, though there is some variation in the thicknesses:—

	Feet.	Inches.		Feet.	Inches.
Coal, impure,	1	0	to	1	3
Slate,	...		„	1	9
Coal, good (Foundry bench),	2	6	„	5	0
Coal, bony,	1	0	„	1	6
Slate,	0	6	„	2	0
Coal, good,	5	0	„	6	0

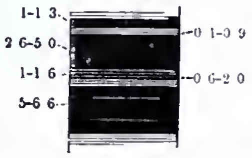


FIG. 268.—Big Coal F, Pinebrook Mines.

BASIN OF PINEBROOK AND THE LACKAWANNA.

The fifth anticlinal, ranging through the Swetland Meadows north of the Lackawanna, must cross the stream in the neighbourhood of the bridge of the plank road. A coal-bed, apparently not a very thick one, outcrops near the bridge. The probability is that this seam is identical with the lower one of the bluff at the Fellows' Mine—namely, Coal G. If such is the case, the basin of the Big Seam of Pinebrook can extend to but a limited distance Northward of the brook; how far up this stream it basins out, has not been ascertained. In consequence of the Westward declension of the two saddles bounding the basin, this trough of the coal itself subsides gently in the same direction. It follows as a physical necessity, that as we pursue it Westward, higher and higher coal-seams will come in, first G, and then H, and finally I and K. Now Coal H, or the Diamond Seam, evidently occupies about the middle of the trough at the river, from the railroad bridge up to the Fellows' Mine, for at this latter spot it rises to the N. bank of the river with a gentle Southward dip, while, a little way above the railroad-crossing, it sinks into the stream with a N. dip on the opposite bank. The actual termination Eastward of the narrow basin of this seam cannot therefore be far Eastward of the Fellows' Mine, and it must be somewhere between this point of the basining-out of the Diamond Seam, and the Pinebrook working of the Big Seam, that the next lower coal, G, must end in a similar spoon-shaped trough. Coal I, in all probability, basins out W. of the Lackawanna, near its bend below Hyde Park bridge, while K terminates its small upper trough on the Fellows' land, near the main road to Scranton.

BASIN OF THE DIAMOND COAL MINES.

We come now to consider the coals and their outcrops in the wide, flat, undulating basin N. of the fifth anticlinal. This, which is the main central basin of the district, is that which embraces the Diamond Mines east of the Swetland Meadows; very little is known of the coal-beds within the belt, but W. it contains all the higher coals of the district. It is needless here to recur to the details already furnished respecting the lesser anticlinal flexures between the main axis No. 5 and the most Northerly known, or No. 9, or to the coal-seams lifted by them to the surface along the Hyde Park Bluff. These flexures are prolonged Westward, but in the absence of mining or surface indications they cannot be traced. The central synclinal, or deeper middle line of the general trough, lies not far, probably about 200 feet, S. of Slope No. 2, and if prolonged so far, it must hold about the same position with reference to Coursen's Shaft at the Hampton Colliery on Keyser's Creek. At both of these localities the basin contains the Diamond Seam, and, as a consequence, all the underlying coals.

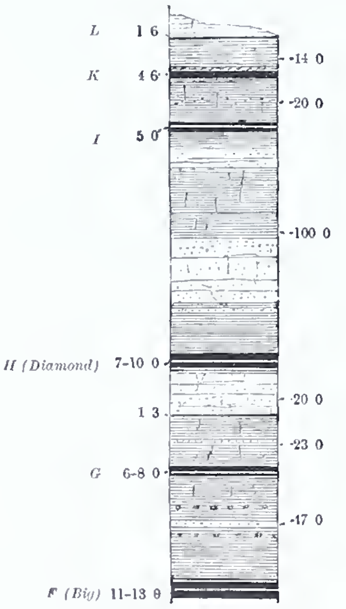


Fig. 269.—General Section, Diamond Mines.

Outcrops.—Commencing with the lower outcrops accessible along the bluff bordering the Swetland Meadows, we may trace them along its base, by the surface-workings of the Diamond

Mines, the whole way from a drift in the Diamond Seam, in a little ravine just W. from the plank road, S. past the Diamond Mines, and the mouth of the ravine at Lewis and Howell's, (known as Silkman's), and past the Old Swetland Drift, until we reach the foot of the little anticlinal ridge, where these two coals are lifted by the arching of anticlinal axis No. 5, and thrown out, to enter the ground again on the S. side of the axis at the Fellows' Mines. Along this bending line of outcrop, these two coals undulate gently over the three intervening anticlinals, Nos. 6, 7, and 8, which are so flat and gentle as to occasion almost no deflection of the gangways within the mines, their tendency being to hold up the coals, and spread them near the surface in a broad expanse, admirably adapted for economic mining. The Diamond Mine-drift enters this coal at the level of the Meadows. A boring here made cut Coal G at a depth of about 43 feet, and penetrated 47 feet lower to the Big Coal F. Adjoining this drift, Slope No. 1 descends obliquely through the measures, separating the Diamond bed from Coal G, to the latter seam. Slope No. 2, further S.W., descends through overlying materials to Coal H. Still further S.W., Shaft No. 2 enters the ground at the foot of the second bluff, and penetrates to the Diamond, or Coal H, at a depth of about 100 feet. From the bottom of this coal in the shaft, a boring has been carried down, cutting Coal G at 10 feet depth, and Coal F 43 feet below the bottom of Coal G. Our section of the shaft exhibits these coals.

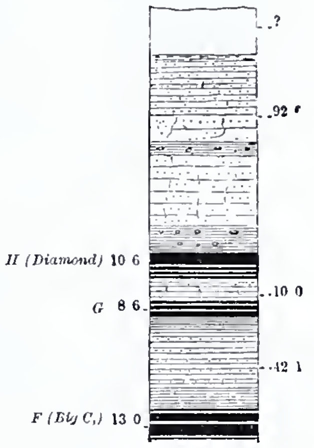


Fig. 270.—Shaft No. 2, Diamond Mines.

Proceeding next to the coal-beds I and K, we find them ranging parallel for many hundred yards along the line of the Northern division of the Delaware, Lackawanna, and Western Railroad, the cuttings of which expose them in some places clearly to view. The outcrop of Coal K is in some places above, in others below the railroad-level, while that of the underlying Coal I runs below the railroad, near the base of the upper bluff. From the Silkman Ravine the outcrop of Coal K may be traced along the face of the upper bluff, or that which immediately supports the village of Hyde Park, running at first S. and then S.W., until, crossing the Scranton and Hyde Park Road, it meets the fifth anticlinal axis. Here an extensive denudation of the strata, forming the S. flank of this very flat saddle, has cut away the South-dipping portion of the coal, and left it with one outcrop, to enter almost horizontally the face of the bluff.

A little W. of the Silkman Ravine, a colliery has been established in the Diamond Seam by Lewis and Howell, access to that coal being had by a slope-mine sunk Westward obliquely through the strata, commencing in the ground between the outcrops of Coals I and K, and cutting the Coal I in its descent to Coal H, in which it terminates.

N.W. of the line of outcrop last traced we are unable to discover any outrising of the coal that can be identified. A few surface-shafts have been sunk, but they lead to no positive results. We feel quite assured, however, that none of the lower coals rise to the surface in the high ground S. of Keyser's Creek; beyond this, however, they outcrop in succession on the flank of the mountain bordering the valley on the N.W.

The following measurements exhibit the thickness and subdivisions of the Diamond Seam, and Coals F and G, at the mines near Scranton.

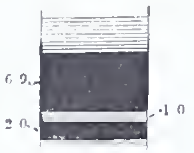


FIG. 271.—Coal H. Washburn Mine.

Coal H, or Diamond Bed, Washburn's Mine—

	Feet.	Inches.
Coal,	6	9
Slate,	1	0
Coal,	2	0

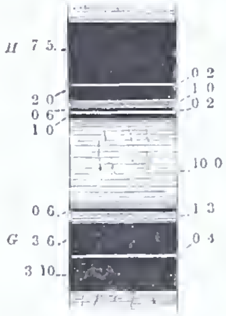


FIG. 272. — Coals H and G, Shaft No. 2, Diamond Mines.

Coal H, Diamond Mine Shaft—

Coal,	7	5
Slate,	0	2
Coal,	2	0
Slate,	1	0
Coal,	0	6
Slate,	0	2
Coal,	1	0

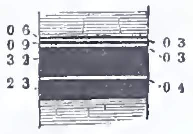


FIG. 273.—Coal G, near the Fellows' Mine.

Coal G, near Fellows' Mine—

Coal,	0	6
Slate,	0	3
Coal,	0	9
Slate,	0	3
Coal,	3	2
Slate,	0	4
Coal,	2–3	0

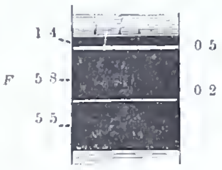


FIG. 274. — Coal F, Shaft No. 2, Diamond Mines.

Coal F, Big Seam, Diamond Mine Shaft—

Coal,	1	4
Slate,	0	5
Coal,	5	8
Slate,	0	2
Coal,	5	5

To bring out in a clearer light the remarkable productiveness of this portion of the lower Coal-measures of the Scranton district, I will present in a tabular form the actual least thicknesses of the several coals within the strata, their net thickness of good coal fit for market, and the computed yield of such coal per acre from each bed.

TABLE.

Coals.	Least Thicknesses.	Good Coal.	Yield of Good Coal per Acre.
K,	5 feet.	3 feet.	4,000 tons.
I,	7 „	4½ „	7,000 „
H,	10 „	7½ „	12,000 „
G,	6 „	3 „	5,000 „
F,	12 „	9 „	15,000 „
D,	8 „	6 „	10,000 „
C,	6 „	4½ „	7,000 „
	54 feet.	37½ feet.	60,000 tons.

These totals hold good, of course, only for those portions of the coal-field which are underlaid by all the seven coals enumerated. If we wish to aggregate the gross amount, the net amount, and the amount per acre, contained in the four middle beds D, F, G, and H, which lie within a thickness of 200 feet of strata, and spread beneath every acre of the central coal-field, excepting only a narrow belt along its S. border, we shall find, on summing up the columns of the table, that the least total thickness of these coals is 36 feet, their yield in thickness of good coal is upwards of 25 feet, and their productiveness per acre 42,000 tons.

In the N.E. portion of the district under consideration, several collieries have been established within a few years, and are in successful operation. These are as follow :—

The Slope Mine of the *New York and Pennsylvania Coal Company*, situated upon Fuller's Creek, a tributary of Legget's Creek. In this mine the Big Coal is wrought, and displays the following dimensions :—

	Feet.	Inches.
Coal, poor,	3	0
Coal,	4	2
Slate and bone coal,	1	2
Coal,	4	8

The coal at this point is of inferior quality, and we learn the Company are about to tunnel Northward to Coal D, which in a drift displays a thickness of 6 feet free from slate. Between the two larger beds a 2-feet seam is displayed in the brook bed.

Clark's Mine.—At this point Coal D is wrought by a slope, sunk Northward to meet it upon a gentle Southward dip. There are one or two water-level gangways entering upon the same bed in the neighbourhood. The coal varies in thickness from 5 to 8 feet.

The *Luzerne Coal Company* have sunk a slope in the Big Seam upon the bank of Legget's Creek ; the dip is Southward. The coal possesses its average dimensions.

N.W. of the village of Providence the high ground evidently contains Coal I, and of course the Diamond bed and the seams beneath it. This has been proved by several borings, upon the basis of which the *Vanstork Coal Company* are about to establish a shaft-colliery. They are reported to have cut Coal I at 100 feet beneath the surface, below which Coal H has been found at the unusual depth of 150 feet. It is said to be 9 feet thick.

Subjoined are the results of a boring made on the flats of the Lackawanna opposite Providence ; how far they are reliable I am unable to say :—

	Feet.	In.		Feet.	In.
Surface material, sand, &c.,	54	3	*Coal,*	1	6
Coal,	6	0	Slate,	0	7
Slate,	3	0	*Coal,*	2	1
Sandstone, hard and white,	22	1	Fireclay, ball ore,	19	10
Slate,	1	0	Sandstone,	3	11
Sand-rock,	18	1	Slate, with ore,	25	7
Coal,	0	6	*Coal,*	6	1
Slate,	18	8	Slate,	0	2
Coal,	0	7	*Coal,*	1	4
Slate, &c.,	10	1	Slate,	6	10

ROAD BETWEEN HYDE PARK AND PITTSTON.

About a quarter of a mile W. of the Meeting-house, on the road (3½ miles from Hyde Park), strong N. dips were seen, followed by decided S. dips, then an undulation and S. dips again. Here seems to be a well-marked anticlinal, crossing the road obliquely. About 200 yards E. of Stewart's Lackawanna Tavern are exposures on the S. side of the road of sharp knobs of South-dipping massive sandstone, and near the road North-dipping rocks, forming a sharp anticlinal turn. On the first hill below this tavern the dips are N. and E. Near the blacksmith's shop, at the road fork, on line between Lackawanna and Pittston townships, a coal is opened, measuring about 7 feet. A little to the N., in a field, is a ledge; dipping N. is another seam geologically above that outcropping on the road.

On the farm of Erastus Smith, near the Northern Road, a road up the back valley on the N. side of the basin, a 7-feet coal has been proved. All the coal hereabout dips to S. rather gently. Smith's opening is situated on the S. side of the North Road near the sawmill. Babb has opened a coal on the flank of the mountain N. of his place, and the Big Bed of Pittston is thought by some to crop out on the mountain. Between the North and Main Road Philips has opened a 7-feet coal.

Above the Old Forge place Drake has opened a 7-feet coal in a hollow leading down to the diluvial plain, in a direction a little E. of S. from the barn at the *fault* or anticlinal seen on the middle or turnpike road. This opening seems to be about 800 feet from the road; the dip is gently N. Farther S., and quite near the N. bank of the Lackawanna, Drake has opened a 5-feet bed, and between this and the other has found proofs of still another coal. The coal of the 7-feet bed is used by the neighbours, and is said to be very good.

At the crossing of the Lackawanna, at Old Forge, there is a long series of exposures of sandstone with gentle N. dips. At Babylon the dip is flat Southward. Near this place a boring was made, near the middle of the river, to a depth of 76 feet, when the machinery was swept away by a freshet. A small coal, 4 inches thick, was cut 60 feet from the surface. A little below Babylon is Massey's Coal, dipping gently S.; it is 8 feet thick, and corresponds to the 7-feet bed at Pittston.

FROM SPRING BROOK TOWARDS SCRANTON, *VIA* THE SOUTH ROAD.

At the point of the first hill or cliff N. of Spring Brook, a sandstone dips very flat Northward from a point 200 yards from the house at the foot of the hill.

Due N. from the foot of the hill, a cliff on the N. side of the Lackawanna flats, about a quarter or a third of a mile distant, exhibits strata dipping gently Northward.

On the first bench of the hill, coarse pebbly sandstone dips 8° N. in a fold about 300 feet N. of the road. This is better seen in a N. dip and gentle roll on the top of the hill, where, though almost flat, its inclination is Northward. A little beyond is a local anticlinal.

The next hill-top displays very flat N. dips. Near the top of it Mr Tuttle has opened a coal 8 feet thick, dipping 5° N. Mr Tuttle says this coal enters the hill-top S. of this locality. He thinks the coal and Drake's on the opposite side of the river are the same. Thus far all the rocks have an average N. dip.

On the creek which crosses the road, the only one on the map, a little way below the road, coal is said to have been dug. Ascending for a considerable distance, and then proceeding, we have a wide flat surface, evidently of nearly horizontal rocks, though no masses are to be seen. Moore's coal-opening on this road displays—

	Feet.	Inches.
Coal, ...	1	6
Slate, ...	1	0
Coal, ...	5	0

In the ravine N. of J. D. Smith's, on the back road from Pittston, about 2½ miles from Scranton, there are two veins—the Coal A, at the head of the ravine, dipping N. about 12°; about 4½ feet have been opened, but it is said to be much thicker below: another, Coal B, is undulated, and displays two outcrops. Some 6½ feet of coal are exposed, but the bed is evidently thicker than this. The dip of slate and coal near the Lackawanna is very decidedly S. On the opposite side of the Lackawanna is Phelps' Mine, sold lately to the New York Company.

STRATA EXPOSED ON THE PENNSYLVANIA COMPANY'S LOADED TRACK RAILROAD FROM PITTSTON TOWARDS SCRANTON.

The top of Plane 2 at Pittston lifts us above the great lower terrace of drift. Here we have good exposures of Coal-measures dipping N. about 15°. A coal is opened to the S. of the track and 20 feet below it. The road keeps nearly on the strike for 2 miles, showing all along the same dip. This brings us opposite Plane 22 of the empty track to the S. On this empty track between Plane 22 and Pittston, the dips, approaching Pittston, are steady, and decidedly S. Between the two tracks there is therefore included an important anticlinal. Half-way up Plane 2 we have the level of a second terrace of drift. Between Planes 3 and 4 the dips seen are undulating, and those towards the N.E. end of the interval are mostly S., but very gentle.

Plane 4 is a superb cut in heavily-bedded sandstone. At the top are seen large faces of North-dipping sandstone, and this dip is repeated all the way to the foot of Plane 5. The road takes a more Southern turn after leaving Plane 4, and cuts into and through the North-dipping conglomerate.

We now move along through the great gorge or natural cut in which both tracks pass. We pass from the conglomerate Southward into the reddish sandstone and sandy shale below, and continue in these rocks a little below the conglomerate to the foot of Plane 5. The conglomerate crosses this plane about midway up, dipping N., and we continue on it to the neighbourhood of Plane 6.

IRON ORES OF THE VICINITY OF SCRANTON.

It has been already mentioned in an early part of this description of the basin, that the Umbral or Red-shale formation of the upper part of the valley of Stafford Meadow Brook, includes a layer or layers of a peculiar variety of iron ore, smelted at the Scranton furnaces.

This belt of ore is known to range for a mile or more with the outcrop of the strata enclosing it, but to the E. and W. of that space it either thins away or becomes too poor in oxide of iron to be recognisable or worth pursuing. Thus no traces of it are to be detected in the prolongation of its outcrop, either in the upper valley of Spring Brook, or in that of Roaring Brook at Cobb's Gap, and it seems to be restricted, or nearly so, to the lands of the Lackawanna Iron and Coal Company.

Its dip is *with* the strata, or towards the N., at an average angle of 15° or 20°, and its topographical position is the East and West-ranging longitudinal valley between the two mountain-ridges, that of the Seral conglomerate and Umbral sandstone on the N., and that of the Vespertine sandstone and conglomerate on the S. The geological situation of the ore is just above the upper layers of the latter formation, or among the lowest of the shales and fireclay beds of the Umbral series.

As exposed at the mines of the Lackawanna Iron and Coal Company on the Stafford Meadow Brook, the ore lies imbedded in a true fireclay or soft clay-shale, the average thickness of which is about 6 feet, while the ore for the most part is in two layers or courses, the lower one a continuous band some 18 inches thick, and the upper one a layer of flat balls or cakes 12 inches or less in vertical diameter. Beneath this ore-stratum is a buff-coloured and greenish sandy shale, and supporting it in turn, a grey compact sandstone, which I deem the upper bed of the great Vespertine or Lowest Carboniferous Series. Above the ore-deposit reposes a bed of close-grained, grey, argillaceous, shaly sandstone, of an average thickness of 30 feet, and in the middle of this lies a band of fireclay one foot thick, containing also scattered balls of iron ore. Over this sandstone occurs a mass of 30 feet of yellow and red shale, more characteristic of the ordinary red shale outside of the coal-basins than any of the other subjacent members of this group of strata, which present, indeed, almost the maximum of deviation from the usual conditions of the Umbral formation. The stratum embracing the iron ore abounds in the same delicate fossil rootlets of the plant called Stigmaria, which are so distinctive of the fireclay beds which support the seams of coal.

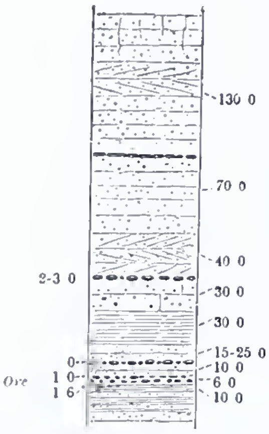


Fig. 275.—Umbral Strata, showing position of Iron Ore, Stafford Meadow Brook. — 1 *inch* = 200 *feet.*

The iron ore itself appears to be a concretionary deposit, collected from the imbedding fireclay and overlying strata at their outcrop. The oxide and carbonate of iron of which it is composed, have been primarily diffused through these rocks, in part, perhaps, under the form of the sulphuret of iron, and subsequently gathered thus into sheets and layers of balls by infiltration of the rain and other surface-waters. In confirmation of this view of the origin of the ore, it appears that the deposit grows less rich in iron wherever it is followed far into the hill, or is covered with tight overlying strata, as to have experienced a less than ordinary share of percolation from the surface. In these positions the ore is little else than a fireclay, with a merely greater than usual impregnation of the oxide of iron.

The ore, as taken from near the outcrop of the beds, where it is extensively mined by shallow drifts and by stripping, is a mottled dark-green and red sub-crystalline mixture of the carbonates of iron and lime with the peroxide and protoxide of iron, containing, besides, alumina and some silica. It is readily fusible, and holding a small amount of the carbonate of lime, it assists materially in fluxing the more refractory ores with which it is mingled in the furnaces. It is of very variable thickness, the proportions of its metallic iron ranging from 25 to 45 per cent. It is impossible at present to make any exact quantitative estimate of the extent of this interesting iron ore along its line of outcrop, so irregular is the topography of the belt it occupies, and so variable are the circumstances which control the presence or absence of that degree of purity which is essential to its being profitably mined and smelted. But that it prevails in great abundance must be obvious from the mere consideration of the long line of outcrop, the wide belt over which it is spread by its gentle dip, and the consequently thin covering under which it lies around the margins of the hills.

IRON ORES OF THE COAL-MEASURES.

Ore of Coal E.—Pursuing, as with the coal-beds, the ascending order, the first bed of iron ore in the Coal-measures of the Scranton Coal-field is the layer of large nodules or balls of clay iron-stone, or argillaceous carbonate of iron, which underlies at an interval of a few feet the large Coal-seam F. The most abundant deposit of these balls is in the Stigmaria shale or fireclay immediately beneath the little Coal-bed E. Here the masses, generally 2 or 3 feet in diameter, lie usually in a single course, the balls not being in contact, but sometimes two or three diameters asunder.

They are of a blue colour, compact and excessively hard, and are of the structure of *Septaria;* that is to say, they have been fissured from the centre outward by shrinkage, and the crevices filled with infiltrated crystalline quartz, brown spar, sulphuret of iron, and sulphuret of zinc. Externally they are of a light bluish-grey colour, and less rich in iron than within, and are marked with the rootlets of the Stigmaria traceable a short way below their surfaces, showing them to be true concretions. Iron made of this ore alone is remarkable for its great toughness and strength, and hence the variety is in much request for mixing with the other ores smelted at the Scranton Iron-works. The principal ore-drifts in this layer are situated upon Roaring Creek, and are quite contiguous to the furnaces.

Blackband Ore of Coal F.—The next layer of ore is a coarse, compact, anthracite *blackband,* occurring in the black slate and shale bed which immediately underlies the great Fourteen-feet seam of coal on the Lackawanna W. of Scranton. This ore is of a bluish-black colour, not very dense in texture, and is between 4 and 5 inches in thickness. Under certain circumstances of mining it might be economically wrought, and would prove a useful ore if mixed with the other varieties. The blackband ores of the anthracite measures are, however, not to be confounded in their properties with the genuine blackband of the bituminous coal-fields, since these latter, by virtue of the bituminous matters which they contain, are much more likely than the former to purify themselves, in the process of roasting or of smelting, from any sulphur which they may contain. This ore contains much carbonaceous matter, and ought therefore to make a good iron after roasting. When reduced to powder, it effervesces actively with *hydrochloric acid,* which shows that it contains some carbonate of lime, another useful constituent tending to facilitate smelting.

Nodular Ores of the Coal-seam K.—In the upper part of the Coal-measures, immediately beneath the Coal-bed K, and also under its rider L, there occur two beds of good nodular clay iron-ore.

The balls which underlie the first named of these coals are irregularly scattered in a blue sandy shale, and unless where very favourably exposed for surface-stripping, are for the most part too coarse and lean in iron to repay the cost of collecting. Those which adjoin the little Coal L occur in its under-clay, a soft argillaceous shale. They are in greatest abundance within 7 feet of the coal-bed, though some occur in a fireclay next beneath this, reposing immediately on the Coal-seam K. These nodules are usually spheroidal in shape, and vary from the size of an egg to one foot in diameter. The quality of this ore is good, it being a tolerably pure, heavy, and nearly homogeneous protocarbonate of iron. The balls weather of an ochreous-brown colour, and exfoliate in concentric scales of peroxide of iron, showing them to contain some carbonate of lime, and to be a little sandy. Under advantageous positions for mining, this ore, the abundance of which is very considerable, may be wrought, both by stripping and drifting, at a cost quite within the limits of economical production.

OTHER IRON ORES SMELTED AT SCRANTON.

Surgent fossiliferous ore is smelted at the Scranton furnaces; it is brought from Clinton County, New York, and costs at the furnace 3 dollars per ton. The ball ore brought one-fourth of a mile from the Coal-measures costs 3 dollars 50 cents. The mountain ore from the mines on Stafford

Meadow Brook, brought 6 miles, costs 1 dollar 75 cents. Limestone, from Limestone Ridge, below Berwick, brought 60 or 70 miles, costs 1 dollar 50 cents per ton. Two tons of the limestone are required to flux out one ton of metal. The mountain-ore makes a very *red short* iron; the Clinton fossiliferous ore a *cold short* metal; the two are therefore smelted together.

ROARING BROOK FALLS.

This waterfall near Scranton is a series of low cascades, followed by a single fall of about 20 feet. The channel of the stream above is worn in the lower plates of the Seral conglomerate, but the principal fall starts from the upper surface of the Umbral rocks, and the wild narrow gorge below is cut out of these rocks. The lower beds of the conglomerate are quite coarse, some of the pebbles being 2 or 3 inches long, and most of them more than one inch in diameter. The higher beds are generally less coarse. About 15 feet above the base, a dark-grey coarse sandstone takes the place of the conglomerate. Above this the rock is conglomeritic, and in some places quite coarse. The thickness of this, as exposed in the grand cliff above the falls, is about 50 feet. The dip of all these rocks is N. about 15° W. at an angle varying from 5° to 12°. The accompanying sketch will convey an idea of the principal fall.

ABSENCE OF COAL IN SPRING BROOK VALLEY, SOUTH OF THE LOADED TRACK.

A gentle Anticlinal, Axis No. VIII., crosses Spring Brook, a little S. of the Empty Track on the W. side. Its S. dips are very flat, being not more than 3°.

From this very gentle flexure not the most trivial dip to the S. is visible all the way up the valley to its turn at Dolph's Mill, where the soft Vespertine rocks outcrop, and are excavated as at the Stafford Meadow Mines. The conglomerate first reaches the water-level of the valley below the road, crossing not more than half a mile above the Empty Track trestling; thence it ascends in an inclined plateau to its last outcrop S. of the East and West Valley of Dolph's Mill. The Umbral formation rises to the bed of the valley at the house half a mile S. of the trestling. It shows nowhere any red shale, but a little reddish sandstone; and its lower beds are calcareous at the foot of Plane No. 5, &c. As might be inferred from this persistency of N. dips, there is no actual basin S. of the Loaded Track to contain even the lowest coals which outcrop N. of it on Spring Brook.

To the E. of Slope No. 3 the coal runs out, for Joel Hale bored about 300 yards to the E. of the slope, beginning on one of the underlying small coals, and he went down about 150 feet, but found no large coal. The dips on the side of the creek are S. 70° E. from the slope.

David Rau & Co. informed us that they bored for coal on the Loaded Track about one-third of a mile N.E. of the head of Plane No. 3. They assert that they have on their land the outcrops of a coal, 8 feet thick, at 100 yards S. of the Loaded Track. The dip is very gentle to the N. Section at Rau's boring :—

	Feet.	Inches.
Hard rock and slate, ...	60	0
Coal, ...	0	18
Sandstone and slate, ...	40	0
Coal, ...	14 ?	0

CHAPTER IV.

THE PITTSTON AND MILL CREEK DISTRICT.

GENERAL SECTION OF THE PITTSTON AND PORT-GRIFFITH COAL-MEASURES.

Before entering upon a systematic description of the anticlinal flexures of the third district of the coal-field, it will be expedient to become acquainted with the strata themselves. These are therefore here illustrated in a columnar section, compiled from observations and measurements made at Pittston and Port-Griffith, and checked by the data derived from the Pennsylvania Company's mines and borings. The Section, which sufficiently explains itself, indicates as many as seven coal-beds above the base of the main Pittston Seam. A comparison of these with the beds of the upper Coal-measures exposed by mining near the mouth of Mill Creek (see fig. 256), shows, even in this short distance, considerable variations, nor is it indeed practicable, in the present superficial and unadvanced state of the mines, to identify all the members of the two groups. The two Sections will, however, much assist the reader to an understanding of the following descriptions of the flexures of the strata, and of the coals contained in the sub-basins.

By the Pittston and Mill Creek District we mean the whole belt of country S. of the Susquehanna, which is embraced between the meridian of Spring Brook and that of the mouth of Mill Creek, including the region S. of this stream and Gardener's Creek, as far as the parallel of the mouth of Laurel Run. This tract includes eleven or twelve regular and parallel anticlinals, characterised for the most part by much less gentle dips than belong to the flexures of the country to the N.E. of Spring Brook. Intermediate between some of these are several subordinate anticlinals of less force and shorter length. These disturb the regular basins of the coal between the larger ones, and materially affect the facility of systematic mining, though they exercise but little influence on the external features of the country; nor are they important in deflecting seriously the outcroppings of the coal-seams.

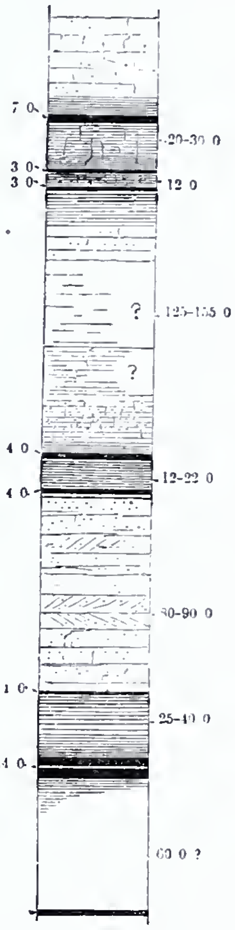


Fig. 276.—General Section, Pittston and Port-Griffith.

The members of this large group of anticlinals are beautifully arranged in an oblique parallelism, or in echelon, from the Lackawanna to Mill Creek.

Axis VI., *or that of Morgan's Mine.*—The first or most Northern of the series, Axis VI. of the Map, crosses Spring Brook and Mill Brook near their entrance into the Lackawanna, ranging in the usual direction, or about S. 70° W. It lifts the upper Pittston Coal to above the water-level in the ridge next S. of the Lackawanna, where it is worked in a mine entering on the arch of the axis at Morgan's Mines. To the N.E. of Spring Brook this anticlinal seems scarcely to be felt, for n its range we meet a great prevalence of N. dips.

Axis VI. A.—North of the axis before us there would seem to be an insignificant shorter one, a little S. of the main road, visible in a coal-drift and ravine a third of a mile S.W. of Babb's.

Axis VII. The next leading anticlinal in due order S. is one of very considerable length, and of an obvious though moderate degree of flexure. It ranges from Spring Brook, where we find it between the trestlings of the empty and loaded tracks of the railroad as they cross Spring Brook Valley, and it passes Mill Brook below the foot of Plane No. 3, being finely exposed on the back road near Barnum's Mine. Thence it extends straight to the termination of the ridge, carrying it to the bluff hill-side E. of the canal, where its N. and S. dips are well developed in the arch of the Pittston Seven-feet Coal, in the S. leg of which occurs Price's, and, in the Northern, Schooley's Mine.

Strata lifted by Axis VII.—This anticlinal, evidently the lowest Coal-measures, elevates at its Eastern development on Spring Brook. Near this line of elevation, on lands owned by Mr Ran, an 8-feet coal, and a still thicker inferior seam, have been proved, the former by mining, the latter, it is alleged, by boring ; and these coals we regard as lying far below the Pittston upper series. The statement respecting the boring is, that, starting below the level of the outcrop of the Eight-feet Coal, it crossed another bed 18 inches thick at the depth of 60 feet, and, 40 feet deeper, ended in a coal 14 feet in thickness. If really a coal 14 feet thick does exist here,—but the absence of any such on Spring Brook throws a strong doubt upon the correctness of the measurement,—it cannot be the Pittston large seam, for the obvious reason that the final outcrop of this is known to lie far to the N. On the back road at Barnum's Mine the arch of the anticlinal embraces the Pittston Seven-feet Coal, or the Port-Griffith Fives (so called) ; and a little to the E. of this outcrop, at a lower level by some 50 or 60 feet, there are topographical and other indications of the presence at the surface of the large Pittston Coal, or the Fourteen-feet bed. Neither of these coals has been traced or identified to any considerable distance E. of this point in the basin N. of this anticlinal. From the point of exposure of the Pittston Seven-feet Coal, on the back road at Barnum's to near the end of the ridge towards the river, this coal, though above the water-level, does not expose any outcrop, being saddled by higher rocks ; but the end of the arch towards the river being cut away, the coal is there denuded and accessible, and has accordingly been mined, as already intimated. The large Pittston bed is not, however, lifted on the back of this anticlinal to the water-level of the Susquehanna.

Axis VII. A.—Between this flexure and that of Morgan's Mine is a feeble swell of the strata arresting their general N. dip. It is seen in the hill a little S. of the Catholic chapel. The effect of this is to lift back the Pittston Seven-feet Coal, and to repeat it in a second N. dip, where it is mined by Benedict. It does not seem that this trivial flexure extends any great distance E. The strata embracing an 8-feet bed of coal visible near the Powder-mill on Spring Brook, have N. dips proceeding from this axis, and to the same flexure concurring with the general tendency of the strata we may refer the N. dips visible between the Spring Brook Valley and the Lackawanna.

Axis VIII., *or that of the Iron Foundry.*—We come now to another anticlinal, quite as extensive as the previous one, and not far from it. We first detect it to the E., on Spring Brook, a few hundred feet above the trestle-work crossing of the empty track. Here the flexure is extremely flat, the S. dip not exceeding perhaps 2°, and the N. not more than 4° or 5°. This anticlinal is conspicuously exposed on the back road on the Barnum ground S. of an abrupt hill, the result of an upthrow or dislocation in the line of the axis. From this point the saddle is traceable to the end of the ridge facing the Susquehanna.

Strata exposed.—At the river the axis is denuded, and the Pittston Seven-feet Coal is laid bare just above the level of the turnpike, opposite the Iron Foundry. The fault connected with this anticlinal, detected by mining operations at the base of the bluff hill adjacent to the back road, uplifts the strata on its N. as much as 50 or 60 feet, placing the Seven-feet Coal, which to the S. of the axis is at the level of the valley, high on the side of the hill to its N. On Spring Brook, about 3 miles to the E. of this point, the strata, exposed in a scarcely perceptible flexure, seem to be those of the very lowest portion of the Coal-measures, for it is only about one-third of a mile to the S. of its position that the conglomerate base of the Coal-bearing rocks rises out to the level of the valley of Spring Brook, the strata in the space between ascending, moreover, with an extremely gentle inclination. It is obvious, that between the valley of Spring Brook and the valley of Mill Brook, along this anticlinal, and indeed on both sides of it, none but the lower Coal-measures are lifted to the surface; nor is it till we cross the Loaded Track, or even approach the main back road, that we meet with what are called the upper Pittston measures. A little S. of that road, however, we may detect the outcrop of the great Pittston Seam swinging N., and then E., for a fourth or a third of a mile, to basin out in the synclinal trough which lies between the axis we are considering and the previously-described anticlinal N. of it. From the neighbourhood of the fault on the back road, to near the end of the ridge at the river, the Pittston Seven-feet Coal-bed is, for the chief part of this distance, saddled over and concealed by higher strata.

This Pittston Seven-feet Coal comes to the water-level at the Tub Spring beyond the bridge, on the main road. (I understand this to be on the first anticlinal axis N. of Pittston.) It then sinks to the N., coming up to the water-level of the valley at Price's Opening at the foot of the next hill, where it is wrought on a S. dip. The next hill is that of the Catholic chapel, containing the next anticlinal, which is broad and flat. This latter axis passes several hundred feet S. of the chapel. Spanning the axis, the coal goes in again at the water-level at Schooley's Drift, about 100 yards S. of the Catholic chapel. Here it passes a little below water-level, and rises again on a very depressed arch, the axis of which is a little N. of the chapel, and, dipping N., is entered at water-level at Benedict's, about 300 yards N.W. of Schooley's. This latter is but a subordinate roll on the N. flank of the previous axis.

Axis IX.—The next anticlinal which claims a place in our account of the principal axes, is that which passes S. of the borough of Pittston. This important and very regular saddle first shows itself in the country between Mill Brook and Spring Brook, but does not, we believe, exist as a perceptible flexure at the valley of the latter stream. It is seen a little W. of Mill Brook, in the ridge just S. of the head of Plane No. 22, where the rock-cuttings on the Empty Track display both its N. and its S. dips, and where one of the lower coal-beds has been entered on the S. flank of the arch. From this intersection the axis, ranging along the summit of the well-defined anticlinal hill, on the S. slope of which runs the Empty Track, is again well shown near the head of Plane No. 2 of the Loaded Track, where the Big Pittston Coal is mined on both its slopes. Passing now a little S. of Plane No. 2, and a few hundred feet to the S. of Shaft No. 1, the axis appears distinctly marked in a well-developed arch, just W. of the Pittston Brook, where the natural exposure of the strata has been assisted by the railroad-cuttings for the Loaded Track.

It ranges through the S. brow of this hill, keeping a little to the N. of the Plank Road, and growing somewhat fainter in its dips, comes out on the canal in the broad gentle arching of the strata, there visible in the higher portion of the sandstone cliffs.

Strata lifted to the Surface by Axis IX.—Lifting, as we have seen, only the lower Coal-measures to the E. of Plane No. 22, this anticlinal in its declension W. allows the upper Pittston coals to saddle it in the vicinity of Plane No. 2. Here, at a distance of about 1000 feet E. from the head of the Plain, the outcrop of the large Pittston Coal-seam swings over the arch of the anticlinal ridge, passing through a depression in its crest from the S. to the N. flank. Further W., at a considerable distance, but concealed by a deep deposit of drift, the upper Pittston Coal, or Seven-feet bed, likewise saddles this axis, but the precise position of this turn, somewhere S. of the foot of Plane No. 2, is not ascertained. In the natural arch W. of the Pittston Brook and the Loaded Track, the large Pittston Coal-bed, which we have seen outcropping so near the head of Plane No. 2, is here 20 feet beneath the bed of the stream, and not accessible to mining except by machinery. At the canal, above the river-side, the small overlying Eighteen-inch seam of coal, 40 feet higher in the strata than the large bed, just lifts itself above the level of the tow-path at the point of the anticlinal, very soon to disappear again ; and here, therefore, the large bed itself lies on the back of the anticlinal, even below the bed of the Susquehanna River.

Basin 9.—In the basin included between this last and the previously-traced anticlinal axis, lie, of course, the lower coals in the vicinity of Mill Brook, and further to the W. the upper Pittston series, basining out as they cross the Loaded Track about 1½ miles from the river. But in this broad synclinal trough are included either three or four subordinate short anticlinal flexures, which we now proceed to describe.

Anticlinal No. IX. A, *or the most Southern visible on Spring Brook.*—The synclinal belt S. of the main anticlinal No. VIII. exhibits on Spring Brook, at a distance of about 1000 feet from that axis, a depressed arching of the strata, the last flexure in our progress S. to be detected, until we pass the conglomerate, or the boundary of the Coal-measures. This saddle is so feeble that its South-dipping portion is almost flat. It may be discerned on both sides of the valley.

Anticlinal No. IX. B.—Coincident in position and direction with the preceding flexure, or Axis No. IX. A, is a more decided arching of the rocks, visible on the road and canal one-fourth of a mile N. of Pittston. It passes the river road close to the spot at which the middle road branches off from this, or just S. of the old tavern.

Though the identity of these two saddles is highly probable, we are unable, in the present state of things, to trace them into each other, and it is therefore most convenient to give them provisionally separate designations.

The Axis No. IX. B exposes at the canal the rocks which immediately overlie the upper Pittston or Seven-feet seam of coal. Even here, at its most W. visible point, this flexure is extremely gentle, its steepest dips not exceeding a very few degrees.

Anticlinal No. IX. C.—This axis shows itself in the canal-cutting close to the S. end of the Pittston Bridge, displaying on the N. turn of the arch a sudden folding of the strata, with marks of dislocation. It lifts to a small height above the level of the canal the Pittston Seven-feet Coal, which otherwise would basin here deeper under the town.

Anticlinal No. IX. D.—A fourth intermediate axis displays itself in the cliffs on the river-side, on the edge of the canal. It is the more North-Eastern and feebler of the two flexures there visible. It is prolonged through the hill, bounded by these cliffs, ranging a few hundred feet N. of the main anticlinal, of which it may be considered a subordinate wave on its N. flank, and passes a little to the N. of Shaft No. 1, the position of which is not far from the centre of the basin embraced between the greater and this lesser axis.

Strata lifted by it.—The effect of this small undulation has been to expand the width of the hill in which it lies, and to spread and hold up the breasts of coal contained between the river-side and the main anticlinal.

Anticlinal No. IX. E.—Connected with the great leading anticlinal we have been describing, is another subordinate one, lying parallel to it on the S., and, like the last small one mentioned, chiefly visible near the W. end of the anticlinal belt. It shows itself S. of the Plank Road, except near the canal, where the axis is N. of this line. But E. of the arch seen on the Loaded Track this saddle is not continuously traceable, but seems rather to be marked by a succession of elongated elliptical upthrows. This line of elevation will pass near the pond adjoining the Loaded Tract.

Anticlinal No. IX. F.—Adjacent to the same anticlinal at its W. end, but several hundred feet to the S. of it, there occurs another short saddle, crossed by the Empty Track not far to the N. of the head of Plane No. 1. This anticlinal is not visible for more than a third of a mile.

These, and perhaps other still more subordinate flexures, undulate the wide Port-Griffith Basin embraced between the main Pittston anticlinal and the important leading flexure which we have next to trace. In this comparatively broad basin of the Port-Griffith Mines we encounter another line of anticlinal uplifts, which either is a continuous axis or a merely linear succession of elliptical upthrows, ranging from a little N. of the Pennsylvania Company's Slope No. 4 across the old stage road at Schaeffer's, and passing just N. of the Port-Griffith Slope No. 1; it is probable, indeed, that this anticlinal commences still further E. in the meridian of Slope No. 4, for such at least is implied in the sweep which the outcrop of the great Pittston bed takes in this vicinity. The actual basin of the Port-Griffith Eight-feet Vein, and likewise of the Pittston Seven-feet, from Schaeffer's eastward at least, is embraced between this anticlinal belt and the larger anticlinal range which next succeeds it on the S. To this latter we will now proceed.

Axis No. X., *or that of Plainville.*—The anticlinal wave to which we have now arrived is apparently not a single axis, but, in its Western part at least, seems double. We meet with it first in the vicinity of Mill Brook, encounter it again in clear development at Yates's, whose farm-house is seated immediately upon the back of the saddle, and we may trace it thence through the crest of the long ridge which ranges W. from his place as far at least as Winter's Lane; here we meet with indications that this anticlinal belt includes in reality two axes, the main one, probably that of Yates's House, passing onward in a strictly straight line close to Williams's Store, and so out to the Plank Road, a fourth of a mile N.E. of the Plank Road Hotel.

Anticlinal No. X. A.—Another or attendant axis, lying some 700 feet to the N. of the main one, seems to range from near the mouth of Winter's Lane along the crest of the ridge just S. of the main road until it passes almost directly by the Methodist Meeting-house, from which point, continuing its course, it ranges through lower ground till it shows itself distinctly in the banks of a brook at the intersection of this with Maxwell's Railroad, whence it is prolonged till it reaches the canal a little W. of the crossing of this by the Plank Road. This main anticlinal, as we regard it passing Williams's Store, is accompanied by another undulation of the strata not 200 feet to the N. of it, the position of which is almost directly under his house.

Strata Elevated.—Of the strata lifted by this anticlinal along the E. part of its range, we know at present very little, except that they must consist of the lower Coal-measures. To the W. of Yates's, however, we find that the Main Pittston Seam laps over this anticlinal arch at the E. end of his hill, and a little further W. is itself saddled over by higher strata—Yates's Mine being here on the S. slope of the wave, and Stout's Opening on the N. From this place the E. limit along this belt of the main Pittston Coal, this valuable stratum, traced forward to the W., keeps under cover throughout the whole broad crest, and under the whole N. flank of the ridge as far as it extends; nor does it outcrop on the S. or opposite side of the axis until it is undulated by another and more subordinate anticlinal, lying some 800 feet or so to the S. of the principal one.

The effect of the principal axis of this anticlinal belt is, as we have seen, to lift the main Pittston Seam high above the water-level in the hill W. of Yates's. But in the vicinity of Williams's Store, estimated to be some 2½ miles from this point, it barely brings to the lower levels of the country the coal which we have called the Pittston Seven-feet Seam, the place of which is at least 120 feet higher in the strata than the main seam above spoken of. We may infer from this, that, in the space of some 3 miles from Yates's to the canal, the anticlinal declines not less than 250 feet.

Basin No. X., *or that North of Axis No.* X.—The broad basin lying to the N. of this anticlinal belt, and bounded on the other side by the main Pittston Axis, contains, as we have already seen, several subordinate short flexures. These occur chiefly in the N. half of the basin, but there is a very feeble one which merely flattens, but does not reverse the dip, passing just at the N. base of the main anticlinal ridge, and to the S. of the New Shaft, No. 5. This we regard as the feeble expression of the anticlinal which we have traced as attendant upon the main one lying N. of it, and passing under the Methodist Meeting-house. As in all the other basins, this N. of the present anticlinal, deepest towards the W., contains there its highest coals, and presents a succession rising out towards the E. of lower and lower strata. The width and consequent depth of this basin is such that it embraces, in the vicinity of Port-Griffith, even a small synclinal patch of a coal found, we believe, nowhere further E. in the whole coal-basin, and which we are disposed to identify with the Nine-feet Seam of the mouth of Mill Creek. This does not, however, possess even enough coal to admit of its being mined. The next subjacent coal of workable dimensions, the Port-Griffith Eight-feet bed, basins out with a spoon-shaped curve only a few hundred feet to the E. of Slope No. 1; and in the same synclinal, the next underlying coal, the Five-feet Twins (so-called), or Pittston Seven-feet bed, have their final Eastward outcrop just a little to the E. the lane of leading S.E. to Yates's.

Within the same basin, though considerably further N. than the synclinal line which marks the basining out of the Port-Griffith Eight-feet and Pittston Seven-feet coals, is the final Eastward outcropping of the main Pittston Seam. This is in that N. subdivision of the chief basin which is called Butler's Basin, and the place of final Eastward outcropping, or the termination of the trough of the large coal, is about one-third of a mile to the E., or rather the N.E., of Butler's Tunnel Mine.

Within this special basin of Butler's Tunnel, the Pittston Seven-feet Seam, here a higher coal by about 70 feet of interval, has itself a basin-shaped outcrop of much more limited extent, the E. point of which is some hundred feet to the W. of Butler's Tunnel. The isolation in this more Northern basin of the Seven-feet Coal from the other already mentioned as near Yates's Lane, is due, of course, to the interposition of an anticlinal flexure—that, in fact, which ranges N. of Slope No. 4, and uplifts the same Seven-feet Coal in the brook at Schaeffer's.

Axis No. XI.—S. of the last-described leading anticlinal, there exists another at a distance of about 800 feet. This is first seen to the E. in the country W. of Mill Brook, and we have it well exposed in the vicinity of Yates's, where it forms a little ridge with a double crest, and divides the small basin of Yates's Coal from another narrow trough of the same bed S. of it. About half a mile W. of Yates's we detect this saddle arched over by the conglomeritic sandstone which underlies at some distance the large coal; and though we meet no exposures indicative of it on Winter's Lane, from the obscurity caused by drift, yet the form of the ground there implies its presence; while still further W. on the lane leading back from near the Methodist Meeting-house, conclusive proofs of this axis are discoverable. Further to the W., we discern no positive traces of it either on the lane running S.E. from Williams's Store, or in the intervening ground.

Strata Elevated.—The effect of this anticlinal upon the Coal-measures is to form, with the main anticlinal of Yates's Ridge, a basining of the coal on the S. flank of the principal axis, and it is at the E. end of this slanting trough that Yates's Mine in the large coal is situated.

Basin XII.—This serves to insulate the narrow trough of the large coal to the S. of it, the last outcropping of which in that direction is determined by the general rise of the country, and the presence of decided N. dips belonging to the next anticlinal. The E. limit of this most Southern basin of the coal is not precisely definable, though it is obvious, from the rising out of of the little valley containing it, and its Westward dip, that the point is but a little to the E. of the meridian of Yates's house. It is this S. basin which includes the openings belonging to Wells, Armstrong, and Bennett.

Axis XII., *or that of Bennett's Big Coal.*—The anticlinal which next succeeds has been but imperfectly determined to the Eastward of Gardiner's Creek. It is that which produces the N. dip of the final outcrop of the main Pittston Coal, and, in virtue of this fact, it possesses considerable interest, for a part of its range it coincides pretty nearly with the course of the back road N. of Gardiner's Creek. This axis, or regular flexure, which we deem it to be, may be seen just N. of the extreme Northern bend of Gardiner's Creek, opposite Venison Hill, lifting the rocks subjacent to the great coal-bed. We may trace it thence, in the topography and in the dip of the strata, to the little brook which passes Maxwell's Mines, in the bed of which stream we may recognise the axis lifting a small coal, which lies next below the great one. A mile and a quarter to the Westward this flexure may be still detected with much enfeebled dips in Carey's Lane, very near his farmhouse; and we have the plainest indication of it, even though in very gentle dips, on the Plank Road, near the canal, about a fourth of a mile above Wordin and Hale's Colliery.

Strata Elevated.—Adverting to the strata lifted by this axis, it is important to remark, that throughout all its range Westward, from its origin to the brook at Maxwell's, it is nowhere saddled by the main Pittston Coal, or any of the upper Coal-measures, but is the immediate barrier which confines their line of outcrop in extending Southward; whereas to the Westward of that brook, the declension and flattening of this anticlinal permits the productive upper measures to arch across it at Williams's Lane, and place their outcrops in the next main basin to the S. of it, till they encounter a deflection from another anticlinal, across which they pass in similar manner to reach the banks of Mill Creek, and vanish under the deep covering of drift which fills the valley of that stream. The lowest strata elevated in the arch of this anticlinal, at its last exhibition on the line of the Plank Road, are those immediately beneath the Hollenback Twelve-feet Coal-bed, a seam which we are disposed to place at an interval of some 100 (?) feet in the series above the horizon of the main Pittston Seam.

Axis XIII.—To the anticlinal last described succeeds another of considerable importance. From the undeveloped condition of the country E. of Gardiner's Creek, it is impossible to trace this axis in that quarter, though the presence there of a saddle in its general line of bearing leads to the inference of its existence. It is first definitely recognised in Venison Hill, and in the two reaches of Gardiner's Creek which enclose this elevated knob. Beyond this to the Westward the saddle shows itself on Williams's Lane about two-fifths of a mile N.W. of the point where the lane crosses the creek. Here an axis, directly in the bearing of that of Venison Hill, exists, which we must regard as the same. Topographical features and anticlinal dips indicate it about a third of a mile further Westward, and we meet evidences of it again in the vicinity of Wilcox's Mine, where the outcrop of the large coal-bed gives indeed ample proof of its presence in the curving sweep which that seam takes Northward and then Northeastward from Mill Creek. We detect what we regard as the same axis at a stage further Westward on the lane leading up the hill near Miner's Mill. The place of this saddle is well defined again on the Old Wilkesbarre and Pittston Road, where it passes very near the dwelling-house of Charles Miner ; thence we may trace it down to the Plank Road and Canal, where, on the bank of the latter, the arch is well exposed, lifting the sandstone strata which next underlie Hollenback's Twelve-feet Coal-bed, the two outcrops of which, upon opposite dips, serve to establish well the form and position of the flexure.

Strata elevated by the Anticlinal.—It thus appears that this axis, in its subsidence Westward, after permitting the main Pittston Coal to saddle it near Wilcox's Mine, allows the higher, Hollenback Seam, to arch nearly over it between the Stage Road and the Canal, marking a declension, in the space of about a mile, of more than 100 feet. That the Hollenback Twelve-feet Coal does not entirely close over the back of the anticlinal is seen in the fact that the mine in this bed on its N. dip, Eastward from the Plank Road, proves to have a separate outcrop all the way to the Old Stage Road, near Mr Charles Miner's barn.

Basin XIII.—Within the basin included between this leading axis and the one preceding it in our description, there occurs an unimportant local flexure visible on Williams's Lane some 600 feet to the Northward of the axis No. XIII. which we have been last discussing. We have been unable to detect any distinct traces of the presence of this undulation Westward of the outcrop of the large coal-seam, but are disposed to impute a part of the Northward displacement of that outcrop near its intersection with a lane leading to Mill Creek, to the gentle lifting of the Coal-measures by this flexure.

The same basin N. of our main axis insulates a trough of the Hollenback Twelve-feet Coal, the E. termination of which must be somewhere S. of Spearing's Tavern. To the Westward of this, and much nearer to the Plank Road, will be found the E. end of the much smaller included or concentric basin of the next higher coal, worked by Wordin and Hale,, the two outcrops of which are visible at their mine :—

Hollenback's Coal.

	Feet.	Inches.
Coal,	1	2
Slate,	0	2
Sound coal,	3½	0
Slate-parting,	0	1
Sound coal (blacksmith),	2	8
Slate,	0	2
Bony coal,	1	2

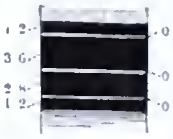


Fig. 277.—Hollenback's Coal at opening near Canal.

All these benches but the lower one are worked.

The Hollenback Coal crops out on the N. side of the basin with a gentle S. dip of 10°. Here it has been entered by a drift.

Axis XIV., *or that of Miner's Mill.*—We come now to an anticlinal, the most Southern of the larger ones embraced within the limits of the Pittston district, as I have defined this, disregarding the township boundaries. This axis, lying about 600 or 700 feet to the S. of that previously mentioned, is well exhibited from the river to the main road; but beyond this the continuity of exposures is so much interrupted by the covering of drift along the valley of Mill Creek, that we discover but few indications of it till we approach the N. side of Gardiner's Creek above its mouth. Here, on the lane leading from that stream to Williams's store, and some 800 feet from the creek, we find a regular gentle anticlinal, which, from its position, we cannot but refer to the axis we are tracing. Again, in the prolongation of this line Eastward through Venison Hill, and still further to the main bend of Gardiner's Creek, when it turns from a N. course to a W. one, we discover very plain evidences of the same axis. That it extends into the district between Gardiner's Creek and Mill Brook there can be very little doubt, but its identification there is not at present practicable.

Strata elevated by Axis XIV.—On Gardiner's Creek this anticlinal, which is the second N. of Thomas's sawmill, lifts out to the surface some of the rather higher members of the lower coal series. The same strata appear to arch it in the ridge N. of the lower reach of Gardiner's Creek. But where this anticlinal passes under the flats of Mill Creek in the vicinity of Miner's Mill, it must be manifestly overlapped by the main Pittston Coal, or the lower members of the upper series, and from this point forward to the river it elevates to the surface higher and higher Coal-measures, the uppermost between the main road and the canal being the 6-feet bed overlying the large Hollenback Seam, and the fourth in descending order from the top of the whole coal series, as we at present know it in the vicinity of the mouth of Mill Creek, or anywhere, indeed, within the region. The point of this anticlinal is well exposed at low water on the shores of the Susquehanna.

Axis XV., *or that S. of Gardiner's Creek.*—The next anticlinal which we may include within this district lies chiefly S. of Gardiner's Creek. It is that seen N. of Thomas's sawmill, some 700 or 800 feet from it. It ranges through Johnson's Cabin Ridge and the Southern part of Venison Hill, crosses Gardiner's Creek in the lane leading thence to Williams's Store, about 1200 feet above the mouth of the stream, being visible in the brow of the hill ascending Northward from the water. The gentle N. dip which we find on the Parson or Back Road just N. of its intersection with Mill Creek, belongs obviously to the Northern flank of this axis; but further Westward than this spot we are prevented from following it, as the wide plain of drift in the valley of Mill Creek effectually conceals the strata. No trace of an axis corresponding to this one has been noticed anywhere in the hill N. of Mill Creek, or the mouth of Laurel Run, in the prolongation of this anticlinal, and we are, therefore, compelled to infer that it dies away in the valley of Mill Creek.

Axis XVI., *or that of the New Haven Mine.*—Succeeding this imperfectly exposed anticlinal, occurs the most Southern well-defined axis of the district. It is that which is so well exposed on the canal, about one-half of a mile below Wilkesbarre, where the very position of the turn of the dip may be detected, and its place identified with the little ravine which separates the two first cliffs or rock-cuttings of the S. bank of the canal. We detect its place again just S. of the deep cut in the Plank Road next S. of Mill Creek, and a third time we find it well exposed in the knoll of the hill on which is seated the School-house, at the separation of the Middle and the Mill Creek roads. From the School-house the anticlinal ranges to near the mouth of Laurel Run, beyond which it is lost for a space under the sheet of drift which fills the valley between Laurel Run and Mill Creek. Traces of this axis reappear again in the topography on the Parson Road, and we have a flexure which we regard as it, beautifully developed, much further E., at what is called the New Haven Coal-opening on Mill Creek, near the mouth of Cold Brook. Further Eastward than this last-named exposure this anticlinal has not been traced.

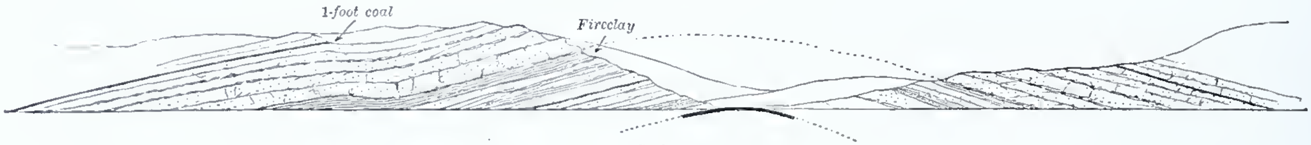


FIG. 278.—Section at the Canal below the mouth of Mill Creek near Wilkesbarre, at the anticlinal flexure No. XVI.

Of the Strata lifted by Axis XVI.—It is impossible specifically to identify the particular Coal-measures elevated by this anticlinal to the surface, throughout all its Eastern range. We feel assured, however, that the coal-bed which so regularly arches the axis on Mill Creek at the New Haven digging is a member of the lower Coal-measures, but almost certainly a higher stratum than the great Baltimore bed. At the Schoolhouse Hill on the Old Stage Road, this anticlinal just exposes, in divided outcrops, the second coal-seam of the upper series, with a small depth of the next subjacent strata. On the Plank Road it barely elevates the same second coal and its fireclays to the surface. On the bank of the canal, on the other hand, in consequence of a deeper denudation at the axis, the next lower or third coal descending is just exposed on the back of the arch at the water-level of the canal. The declension Westward of this anticlinal would thus appear to be extremely gentle.

Basin XVI.—The basin or trough enclosed between the flexure we have just been tracing, and that of the vicinity of Miner's Mill, or the first one N. of the mouth of Mill Creek, has its synclinal line very near the intersection of the Old Stage Road and Mill Creek. Indeed, the lower reach of this stream lies but a little N. of this deepest line of the trough. Within this trough, from the river to that part of Mill Creek extending from the mouth of Laurel Run to Miner's Mill, we have the uppermost or Wilkesbarre coal series exposed on both their N. and S. outcrops, as any one may easily discern who will closely inspect the strata intersected by the canal, or by the Plank Road, or by the old road leading to Pittston. These coals are the first and second descending, and on the N. side of the basin of the Plank Road the third or 9-feet seam is visible likewise on the river-side immediately N. of the aqueduct which spans the mouth of Mill Creek.

Basin XVII.—South of the anticlinal belt which we have last been tracing, there is a broad belt extending in length the whole distance from Wilkesbarre eastward to the upper part of Mill Creek, remarkable for the paucity of exposures of the strata, and for the consequent obscurity which rests upon it as regards its geological structure. Separating as it does the Pittston and lower Mill Creek Coal-measures from those exposed S. of Wilkesbarre, it cuts us off effectually, for the present, in every effort we may make to connect and relate the lower series of coal-rocks and coal-beds embraced between the conglomerate of the Southern margin of the valley, and this belt, with those upper members lying on the other side of the anticlinal, and which extend from it to the river and the Lackawanna. Nevertheless, we do not despair of linking together the two groups at some future day, when the middle parts of the formation, cut by the waters of Gardiner's Creek and Mill Creek, shall have been developed by systematic mining. Within this obscure tract there are all the topographical indications of a flat anticlinal in the vale E. of Wilkesbarre. The position we would assign to it is the rounded summit of the very regular low ridge passing through the farm of Judge Conyngham. If the strata whose outcrops are concealed under the smooth fields and meadows of this valley were once exposed, by either a systematic line of trial-shafts, or by one or more deep borings judiciously located, the whole problem of the relations of the upper to the lower coal series of the Wyoming coal-basin might be readily solved, and some very important practical questions—that, for example, of the depth of the Baltimore coal-bed under the town of Wilkesbarre—satisfactorily answered.

WORKS OF THE PENNSYLVANIA COAL COMPANY AT PITTSTON.

1. *Shaft No.* 4.—This shaft is immediately S. of the Pennsylvania Company's office; it has a depth of 100 feet. The coal was reached 76 feet below the surface; it is in Basin IX., the strata dipping gently N., though there is said to be a small roll in the rocks.

2. *Shaft No.* 3 is about 200 feet S.E. of No. 4, and in the same ravine; it is sunk 98 feet to the 14-feet Pittston vein (which lies in four benches, and contains from 12 to 13 feet of good coal). The dip is gently to the N. The crop of this vein on N. dip is not far S. of the head of this shaft, which is in Basin IX.

3. Back from Shaft No. 3 are the mouths of two sand-tunnels immediately side by side. The Easternmost of these goes in under the hill which lies to the E. of it, into the Big Vein. The other (the Grand Tunnel) is without breast, being covered to prevent the ingress of sand. It follows the ravine (having on its course one or two shafts sunk upon it to procure sand) back as far as the slope now in operation. Before reaching the slope, from which it is designed to carry the coal, it goes through blue sandstone.

4. *The Slope* is rather gently but variably South-dipping, say from 10° to 15°, for 600 feet, when it meets a basin; its end at 750 feet is gently North-dipping. There is, therefore, an anticlinal between Shaft No. 3 and this slope, and a synclinal in the slope. All the mining operations of the Company are regarded as being on the same vein (the 14-feet coal). N. of the slope about 50 feet, a shaft is sunk for the purpose merely of raising the rock cut in the Grand Tunnel, now being driven to the coal.

5. *Shaft No.* 2 is down 87 feet; it may be seen in the next transverse ravine S.W. of that in which Nos. 3 and 4 are situated, about half a mile S. of the Plank Road. The coal (the 14-feet vein) is said to have a gentle N. dip, the shaft being within 100 feet S. of the middle of the basin.

6. *Shaft No.* 1 is situated in the mouth of the ravine on the S. side of the Plank Road. It is sunk 101 feet to the coal, which dips gently S. Behind the shaft, in the bed of the creek, are S. dips in flaggy sandstone. This shaft is near the middle of the small basin N. of Axis IX.

Between shafts No. 1 and 2 and about 1000 feet N. of No. 2, the No. 2 shaft coal rises to the surface, where it has been proved on a S. dip; N. of this the coal disappears, and no N. dips have been found at this locality. In working S. from the foot of No. 1, the coal-bed, in a basin, comes to an abrupt break, from which it entirely disappears, and its place is occupied by sand and drift. It has evidently been torn away by drift, for buried up in the sand are found boulders of coal, bearing evident traces of the transporting action of water.

7. At the upper end of the ravine are several drifts, on what is regarded by the Company as the final outcrop of the Big Vein. This outcrop is traceable Eastward to Butler's, and half a mile Westward to the slopes of the Company.

There is apparently a gentle basin near the trestle of the inclined plane over the Plank Road N.E. of Pittston, or rather a flattening and slight turn from the N. dip at the Mill.

The 1*st Pittston Anticlinal Axis,* or Axis IX. C of the Map, is at the Mill; it lifts the 7-feet coal (so called), or true 5-feet bed, to above the level of the canal about 30 feet in the ravine.

The 2*d Anticlinal,* or Axis VIII., comes to the Plank Road opposite the Foundry. There is an intermediate roll at the Old Tavern, which does not, however, lift the 5-feet coal to the surface, though the 2d Axis *does* so just N. of the brook: it is that of the *fault.*

The 3*d Axis,* or Anticlinal VII. of the Map, is the axis of the Barnum Mine; it comes to the Plank Road between Pierce's and Schooley's mines.

The 4*th Axis,* or VII. A, is a gentle roll, affecting the Schooley's and Benedict's mines; it is not seen on the Back Road.

The line of outcrop of the Big Pittston Coal, on the N. side of the main Pittston axis, after crossing the ridge of Plane No. 2, sweeps down the side of the hill, and, taking the ravine of a small brook, crosses the Loaded Track quite obliquely. The 7-feet, or true 5-feet coal has its outcrop a quarter of a mile to the W. of the large brook crossing the railroad in a similar manner.

The two coals basin in this synclinal trough of the Empty Track about opposite Barnum's Mine on the Back Road.

On the N. rise the strata take a sudden upthrow by a *fault,* to the extent, it is said, of 50 or 60 feet, lifting the 5-feet coals, which are on the side of the ridge, in a flattish N. dip. This fault is probably a part of the axis of this ridge, which is the same anticlinal which reaches the Plank Road at the Foundry. Basining again, the coals spread once more further E. in the narrower and flatter trough between this dislocated axis and the Barnum axis.

This Barnum axis is No. 3 of the Plank Road, or No. VII. of the Map, bringing the 7-feet coal and the 5-feet coal to the surface on the Back Road at Barnum's Mine, where it has been opened near the saddle on a gentle N. dip.

The 5-feet coal comes out near the Plank Road on both dips; it was at one time mined upon the S. dip, nearly in the basin, by Pierce, and on the N. dip in the next basin by Schooley.

N. of this 3d axis, or No. VII., there is no flexure of much force, and only two are visible between it and the Lackawanna. The more Southern of these is that just S. of Benedict's Mine, or a little S. of the Catholic chapel. The other, or N. one, merely lifts Morgan's 7-feet or 5-feet coal to a sufficient level above the canal to allow him to mine it.

The axis of Morgan's Mine is traceable at the bridges on Mill Brook and Spring Brook on the Old Back Road.

These axes, the 3d inclusive, must determine the course of the Big Coal beyond where we see its outcrop, and I doubt not its range is no longer Northward, but North-eastward, or still more Eastward.

In all this quarter the 14-feet coal is reduced to about 8 feet in thickness. May it not therefore be one of the coals near the Lackawanna in the vicinity of Drake's, its identity being lost to observation?

New Mines of the Pennsylvania Coal Company.—This Company's new shaft, No. 5, on the S. edge of Basin X. (see Map), is now sunk to the Big Pittston Coal. Its depth is about 300 feet to the bottom of the coal-bed. The Shaft No. 6, further N. and down the hill, is about 400 feet deep to the same main coal-seam.

Slope No. 2, near Port Griffith, has a perpendicular depth of 415 feet. When it reaches the bottom of the basin, and can drain it, the whole colliery will be in a very fine condition. An inclined plane will let down the coal from Shaft No. 5 at the road to the level of No. 6.

Shaft No. 5 is 10 feet wide by 16 feet long. The average cost of such a shaft in the harder sandstone rocks is about 95 dollars per yard, and 65 dollars per yard for the softer slates, &c.

Shaft No. 7 is in the ravine of the stream, and 600 feet S. of the intersection of the road and the anticlinal axis; it is not deep, is 9½ feet wide by 17½ long, and cuts a small coal very near its mouth, but at the date of our observations (1854) had not yet reached the other upper coal-beds exposed at the anticlinal axis on the road. This shaft is intended to meet the large coal-bed.

Port Griffith.—The Port Griffith section borings were confirmed by outside observations.

	Feet.
Port Griffith Coal,	7
Small pebbly sandstone,	30
Coal,	3

There are the remains of a large coal above the Port Griffith 7-feet coal, at Port Griffith.

The Port Griffith 7-feet coal probably does not reach 1000 feet E. of the Port Griffith slope. It seems to be merely the end of the basin or spoon. There are three gangways running round it. The bottom of the slope runs into the bottom of the basin; the top of it is to the N. of the synclinal line.

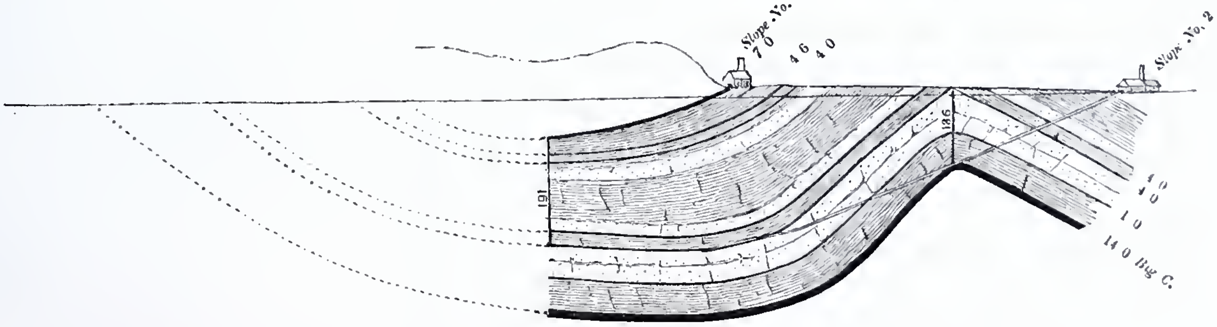


Fig. 279.—Section, Port Griffith Slopes and Borings, from Pennsylvania Company's draught.

Port Griffith Slope No. 2 was sunk to meet the 14-feet coal in its large basin. It begins in the rocks, and cuts the double 5-feet coal, and reaches the 14-feet coal just at its anticlinal axis. It continues in it a short distance, when this 14-feet coal dips down steeply out of the line of the slope.

The small coal in the stream N. of Shaft No. 6 is above the pebbly rock, and about 50 feet above the small coal 40 feet down in the shaft.

COAL-MINES TRACED FROM WILCOX'S N.E. TOWARDS PITTSTON.

At the Wilcox Mine on Mill Creek the dip is S. 20° W., and this dip is seen at several exposures on the creek until we get below Miner's Mill.

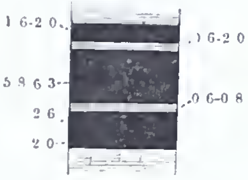


FIG. 280.—Maxwell's Coal.

The upper and lower beds were traced forward to Maxwell's, who was working the upper bed. The small coal which he reached in the tunnel is the small coal between the two main seams.

From Maxwell's we traced the outcroppings of the benches to the opening and boring on Isaac Wilcox's land, thence to the Ben Swallow place at the foot of the orchard S. of the house. Near this we found *the same lower* bed entering the hill S. of the valley, and rising through the hill on its N. dip, to crop out again at Bennett's Mine.

Here the upper bed, still capped by the conglomeritic sandstone, has been opened, but the state of it could not be ascertained: it is evidently thinner than the lower bed. At this place the strata (fissile sandstone and sandy shale) are not less than 70 or 80 feet thick.

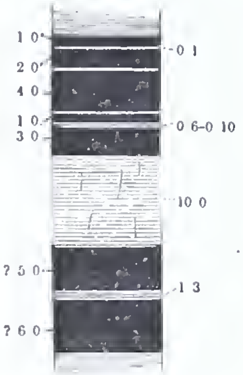


FIG. 281.—Wilcox Coal, Miner's Mill.

This lower bed of Bennett's Opening is 14 feet thick, and contains excellent coal. Even at Williams's the dividing measures are thicker than at Wilcox's Mine. Near Miner's Mill and at Maxwell's they are somewhat thicker and still more sandy, and so they increase in coarseness and thickness all the way to the vicinity of Yates's, in the Pittston Section.

The overlying material is a thinly-bedded grey micaceous sandstone, and immediately over the coal lies a sandy plate. It grows thicker and coarser as we go Eastward; and from the Plainsville Lane a conglomeritic character begins, which forms thence Eastward quite a prominent ridge, from the hardness imparted by the coarseness of the pebbles.

Approaching Yates's, and on Taggart's and Priestley's place, just N. of the valley of the outcrop of the coal, a new feature is displayed in the introduction of an anticlinal axis (No. XI.), which, between Bennett's outcrop and Yates's south-dipping portion of the same bed, forms a distinct basin of this great coal-seam or seams. Opposite Yates's there would appear to be, in fact, two saddles, one (Axis X) at his house, forming the S. dip of his coal-mine, and another in a small ridge to the S. of the mine.

This saddle X is seen at the S. edge of the wood, on the Priestley and Taggart land, lifting the conglomeritic sandstone, the same as at Yates's house, above the level of the meadow. Thus the Maxwell, Bennett and Wells, and Armstrong openings, are on the S. side of one basin, and the Yates Mine is in the basin next to the N.

This small dividing saddle is probably that which passes N. of Maxwell's Mine, while that of

Yates's house must be the more conspicuous one on the main road. The small saddle S. of Yates's lifts the Little Coal to the surface just at the axis, while the larger one lifts only the overlying conglomeritic sandstone at his quarry.

The main outcrop of the Wilcox Coal, going Eastward, swings from a N.E. to an E. course at Maxwell's house, showing the breadth and declension Westward of the wide anticlinal, on the N. flank of which it reposes.

The upper bench of coal over the main lower coal of the Wilcox and Bennett's outcrop, seems to have left this latter by a wide interval when we get as far as Armstrong's Mine.

The Large or 14-feet Coal in the basin N. of Yates's small anticlinal does not extend far to the E. of Yates's land, for it is there opened on the outcrop on the S. side of its basin, where this is quite narrow. From the slope of the Little Valley it is plain that the Little Coal soon lifts itself out Eastward, turning its line of outcrop like the lip of a spoon round the bowl.

On the lane from Yates's out to the main road, we soon meet gentle S. dips, making a flattish basin on the N. side of Yates's main axis. Nearer the E. end of the basin, the Upper Coal—the Wilcox Twins, a bed of Pittston Coal 7 feet thick, dipping W. under the conglomeritic sandstone—is identical in aspect with that which caps the upper Wilcox Coal from the Plainsville or Williams's Lane to Yates's. A little nearer the main road we cross the broad flattish saddle exposed in S.W. and W. dips rounding this same capping rock.

On the main road at Schaeffer's the axis is finely intersected in the ravine of a brook, and lifts a coal, the upper of the 5-feet coals or Twins (?) to the level of the brook, exposing 5 feet of coal overlaid by flaggy sandstone 5 feet thick, and the pebbly rock 20 feet more.

A little W. of Schaeffer's Mill is a synclinal ridge on the road, which exposes both dips of the next higher conglomeritic sandstone, and then a long succession of N. dips brings up the lower conglomeritic sandstone capping the 7-feet bed near the new shaft of the Pennsylvania Company. This conglomerate crosses the road E. of Squire Winter's.

At Cooper Farman's opening there is a coal said to be the 7-feet bed.

At Enough and Tulla the 5-feet Coal seems to be in one bed, and it is 8 feet thick; while at Barnum's the 14-feet seam is reduced to 10 feet of good coal.

We traced the outcrop of the Big Coal and the 5-feet Coal, beginning where the outcrop crosses the Loaded Track. The coal seen in the brook dips to the N. 15°, W. 15°. It is said to be in all this E. district not more than 8 feet thick, having lost its lower tier, or the two lower tiers having thinned down; while in this region the 5-feet or 7-feet Coal has 7 feet or even more of good coal in it.

Plainsville.—At Mr Swallow's house there is a coal 5 feet thick, with a N. dip, which was thought by Mr Williams to be the same which was mined near his store at the end of the lane at Plainsville. The same coal crops out on the road between his house and the Methodist Meeting-house, 70 feet S.E. of Mr Swallow's barn; he bored 80 feet through a slate rock, and reached a 7-feet coal: he did not go through the coal, and which coal-seam it is cannot be known.

There is a well-marked anticlinal passing under the Methodist Meeting-house on the Main Road. It bears S. 75° W., and ranges for the saddle seen in the brook on Maxwell's Railroad.

There are two anticlinals between this and Maxwell's Coal—one at Williams's house, and one S. of it, seen about 200 feet S. of Williams's store.

CHAPTER V.

WILKESBARRE, NANTICOKE, AND SHICKSHINNY DISTRICT.

Between Laurel Run, or Mill Creek, and the W. end of the coal-field at Shickshinny, the whole district S. of the Susquehanna constitutes one natural division of the Wyoming Basin, which may be appropriately designated as the Wilkesbarre, Nanticoke, and Shickshinny district.

It is remarkable for the great length and general parallelism of its included anticlinal and synclinal flexures; two or three extend almost continuously throughout its whole length, rendering it inconvenient for us to subdivide it, as we should, but for this, into an Eastern and Western sub-district. The anticlinals of this portion of the coal-field are approximately parallel with the S. boundary or outcrop of the general coal-basin, which, from Solomon's Gap to its intersection by the Susquehanna River below Shickshinny, is remarkably straight. Another general fact connected with the anticlinals and included basins pertaining to this district, is the difference in their general direction, comparing them with those of the Pittston group. We have already seen how these latter deviate by several degrees from strict parallelism with the axis-lines of the flexures of the Lackawanna, and we may now notice a like departure to a direction somewhat more E. and W. in the group of undulations before us. The average difference in range by compass between those of the Wilkesbarre and Nanticoke district, and those of the Pittston region, is not less than 7°.

Though the large district we are describing includes a considerable number of anticlinal undulations, as many as six prominent ones on an average, the whole district may be more conveniently and correctly viewed as made up of three leading troughs, or long undulated synclinal belts or basins, and two principal interposed anticlinal tracts. The most Northern of these, or Basin XVII. of the general enumeration, is that which is sometimes called the River Basin, or the synclinal zone which contains the borough of Wilkesbarre and the village of Nanticoke. The next or middle one, No. XVIII., is the long synclinal belt or basin which embraces the village of Newtown and that of Newport Centre; while the third or Southern general basin, or No. XIX., is that which lies next adjacent to the foot of the Little Mountain, the S. barrier of the coal-field.

We shall now proceed to a more detailed description of these several basins, with the subordinate anticlinal undulations which they contain, and to that of the anticlinal belts which divide them.

Synclinal Belt, or General Basin, No. XVII.—Observing the order adopted throughout our description of this coal-field, or that which takes us S. or S.W. across the valley, but Westward along each individual anticlinal and synclinal belt, the first zone which offers itself for detailed examination is that of Wilkesbarre and Nanticoke. This is bounded on its N. by the anticlinal No. XVI., separating it from the basin of Mill Creek, and also by the flats of the Susquehanna as far as the Nanticoke Notch, beyond which the River Mountain is its boundary. Its Southern limit is the chain of anticlinals called No. XVII., or that line of flexures which, bounding the mines of the Baltimore Company on the S., and ranging N. of Newtown, passes likewise N. of Newport Centre, and thence N. of the middle branch of the Nanticoke Creek.

Several seemingly independent anticlinal flexures, at least six in number, undulate more or less the strata embraced within this large and richly-stored sub-basin of the coal-field. A special definition of these, and of their effects upon the strata, is essential to a full understanding of the course and distribution of the coal-seams included in the basin. Commencing at its E. end, the first of these, as far as they are at present known, is—

Anticlinal A *of Basin* 17.—This is the obscurely-indicated anticlinal flexure which ranges centrally along the little valley extending from Laurel Run to the S.E. corner of the town-plot of Wilkesbarre, and which I have supposed to cross Coal Brook a few hundred feet N. of the Old Still-House coal opening, and to range through the summit of the low flat ridge, over which runs Judge Conyngham's Lane. No distinct outcrop of the strata exists to prove such a flexure, though its presence is strongly indicated in all the features of the surface, and in the fact that a low anticlinal flexure in this position is implied by the great breadth of North-dipping strata visible both to the S. and to the N. of it, implying a thicker sequence of the Coal-measures than on the hypothesis of no such axis we know to prevail within this neighbourhood. It is not possible to suggest, with any approach to certainty, the particular part of the Coal-measures which this axis brings out to the surface ; but as a hint, it may be useful to call attention to the possible identity of the Still-House Coal of Mr Butler's Meadow, stated to be 10 feet thick, with the Hollenback or 10-feet thick bed, next over the large Pittston Seam. It is upon the presence, indeed, of a bed of this alleged thickness, in this position, that I rest in part my inference of the existence of an anticlinal undulation running along the valley through the Butler and Conyngham farms.

Anticlinal B *of Basin* 17.—A little to the S. of the drift-covered plain, supporting the borough of Wilkesbarre, we detect the first well-developed anticlinal flexure in the basin, and we may trace it ranging along the brow of the hill next S. and S.W. of the town. Both of the dips of this arch are to be seen on the Easton Turnpike, and likewise on Market Street, where it leads up the hill. At these intersections it is about 1000 feet S.E. of the canal, and we encounter it again at nearly the same distance on the Tamaqua Turnpike. We again find the axis on the lane running Southward from the Middle Road, from a little W. of South Wilkesbarre, the centre of the arch a little more depressed and feeble, being about 600 feet S.E. of the Whitehaven Railroad. The flexure disappears to the W. of this point, under the superficial materials which cover the valley of Solomon's Creek, beyond which we detect no traces of it. Whether this gentle flexure prolongs itself any distance to the Eastward of Wilkesbarre, or exists there in any greater force than as a mere roll discernible only in mining, is very doubtful. To the N. of the Baltimore Company's Shaft it can exert but a trivial effect, if indeed it extends itself as far as the ravine of Coal Brook, for E. of this we meet with nothing but N. dips in the line of its prolongation.

Strata elevated by the Anticlinal B *of Basin* 17.—This anticlinal elevates to the surface a small coal-seam on the roads leading S.E. from Wilkesbarre, and the same coal, to all appearance, is brought by it to the day, both on the Tamaqua Turnpike and on the lane near the railroad. The coal of the two latter localities is certainly that which has been mined at South Wilkesbarre at the side of the Whitehaven Railroad, in the basin N. of the anticlinal. But this coal is evidently the same as that exposed near the Powder Mill at Quick's, and is that also of the small slope-mine one-third of a mile further W. ; and it is the same in all probability with Siveley's Coal, mined on the N. brow of the next large hill to the Westward, where the outcrop is only a few hundred feet S. of the crossing of the River Road over Solomon's Creek.

In our compilation of the Coal-measures, commencing with the conglomerate, as exposed in the Section from Solomon's Gap to this intersection of the Creek and River Road, we enumerate twelve workable coal-beds—the seam which we have now been tracing, being next to the uppermost, or the eleventh from the bottom. This anticlinal is situated only a few hundred feet S. of the main synclinal line of the River Basin.

Anticlinal C *of Basin* 17.—The next anticlinal of Basin 17, whose position is to be indicated, is one of apparently limited length, situated S. of the River Road, in the vicinity of the Green, or the Lutheran Church. The axis of this flexure may be detected on the lane leading S.E. from near the church, at the distance of about 800 feet from the River Road. The anticlinal structure at this point, and for half a mile Eastward along the ridge which the axis occupies, is distinctly marked in the features of the ground; its position is but a few hundred feet to the N. of the general synclinal axis of the basin.

An outcrop of a coal-seam is visible near this anticlinal axis, and is obviously one of the higher beds of the district, possibly the Siveley Coal itself. The dips on the flanks of this axis are all gentle; the S. ones, which are the most considerable, not exceeding 30°.

Anticlinal D *of Basin* 17, *or that of the Luthern Church at the Green.*—The anticlinal flexure now before us first shows itself on the River Road, or a little S. of it, near Dilley's, half a mile E. of the Green, being indicated on the road by a very gentle Northward dip in thin-bedded sandstones on the summit of the hill. From this point it ranges S.W., and passes almost immediately under the Lutheran Church, where the flexure is still a gentle one. The furthest point Westward at which it can be detected, is on Steele's Lane leading down from the road towards the river, where the N. dip does not exceed 5°.

This anticlinal lifts to the surface the Coal-measures next beneath the Siveley Coal-bed: but its influence as a subordinate undulation in the General Basin is very trivial.

Anticlinal E, *or that of the Nanticoke Mill.*—The next anticlinal flexure which we encounter in the River Basin, is one which may be seen rising Westward from beneath a covering of drift gravel, just W. of the Nanticoke Creek at the Nanticoke Mill. From this point Westward, its course, for a short distance, nearly coincides with that of the N. road at the foot of the River Mountain; but it soon leaves the road, and ranges forward for 2 miles, as a depressed undulation on the flank of the mountain, high on the Southern slope of which it loses itself in an indentation in its crest. Throughout its course, the dips belonging to this flexure are gentle, and its influence therefore in undulating the coal cannot be serious. At the Mill, the N. dip is only 10°, while the S. dip, as shown in the coal-beds, outcropping along the S. bank of the Nanticoke Creek, amounts to about 30°. At the intersection of this axis with the creek, the lowest coal-seam lifted to the surface appears to be the third in the series, though possibly it is the fourth above the thick lowermost bed of the basin, or that called Lee's, at Nanticoke. Still higher coals dip from this axis Southward, outcropping in succession along the Nanticoke Creek.

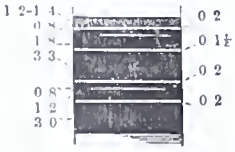


FIG. 282.—Lee's Coal, W. side of Nanticoke Gap.

The size and composition of Lee's valuable coal-bed is here shown. It is extensively mined on the W. side of the river at Nanticoke. The coal of its best benches is in much repute.

Anticlinal F *of Basin* 17, *or that N. of the Gruver Schoolhouse.*—The sixth anticlinal, and the next to be mentioned in the River Basin, lies between the preceding, at a distance of about

1100 feet from it and Nanticoke Creek. It originates in the hill next N. of the Creek, and at a little distance W. of the mouth of Lee's Creek, and is crossed by the N. road of the basin about $1\frac{1}{4}$ miles W. of the Nanticoke Mill, the very arch of the axis being well exposed where the road descends to cross a small brook. From this point it ranges forward N. of the Gruver Schoolhouse, obliquely ascending the flank of the River Mountain, until we lose the last traces of it in the large indentation in the crest of the mountain through which the road passes over from the Coalfield to the Susquehanna River. Like the preceding axis (axis E), the flexure before us is a gentle one, its N. dips especially being very feeble. Both of these probably merely flatten the South-dipping strata of the mountain along the W. half of their course; but their influence, nevertheless, must be sufficient to give a wide double sweep to the outcrops of the lower Coal-beds, especially to that of the great one which overlies the conglomerate.

Anticlinal G, *or that of the N. Branch of Nanticoke Creek.*—The last axis which we have to specify as occurring in the River Basin belongs to its Western extremity, or the valley of the N. Branch of Nanticoke Creek. The N. and S. dips, establishing the existence of this flexure, are to be seen on the road leading from Newport Centre to the Gruver Schoolhouse. The N. Branch of Nanticoke Creek seems to flow nearly on the back of the anticlinal for the lowest mile of its course. Westward from this the axis takes the hill S. of the road which leads over the mountain to the river. This anticlinal appears to be accompanied throughout by only gentle dips.

POSITION OF THE MAIN SYNCLINAL AXIS OF THE RIVER-BASIN.

A subordinate synclinal trough, the most North-eastern of the basin, ranges from the junction of Laurel Run with Mill Creek to the synclinal hill at the angle of the Canal, near its intersection with the Plank Road, crossing the Plank Road obliquely a little E. of the town-plot of Wilkesbarre. This basin includes perhaps the highest Coal-measures or Coal-seams anywhere to be met with in the River Basin; the upper bed on the Plank Road being the eighth of all dimensions, great and small, above the Wilcox or Pittston large seam, and the fourth or fifth of workable size. See the Section southward from the mouth of the Mill Creek.

The main synclinal axis of the general River Basin is not, however, the one above described, which vanishes, or is at least cut off at the river; but it is a much longer one, first discernible on the Susquehanna and Lehigh Railroad, just S. of South Wilkesbarre, and traceable thence across Solomon's Creek, and across Behe's and Butler's creeks, till we lose it S. of Nanticoke. The synclinal axis, or line of greatest depression of the basin, crosses Solomon's Creek only a few hundred feet S. of Quick's house on the River Road. It is marked by a depression in the hills midway between Inman's and Siveley's outcroppings of the upper coals, and passes a few hundred feet N. of Behe's Pond, and about as far S. of the Red Tavern. We thence trace it across Behe's Creek near the deep boring, and through the synclinal hill next S. of the River Road. Westward from this vicinity the keel-line of the basin is less distinctly traceable; it evidently approaches the S. side of the trough, being but a few hundred feet N. of the anticlinal boundary of the basin, Axis No. 17, on the farm of the late Solomon Fairchild. This displacement Southward is the consequence of a widening of the belt of gentle S. dip in the neighbourhood S. of Nanticoke, a widening which is due to the dying down Eastward of some of the oblique anticlinals of the River Mountain originating N. of Nanticoke Creek.

COAL-MEASURES CONTAINED IN THE RIVER-BASIN W. OF WILKESBARRE.

It has been already intimated that the highest Coal-bed embraced within the River Basin W. of Wilkesbarre, is that exposed at the level of the railroad near South Wilkesbarre, and that this is probably the twelfth or thirteenth in the ascending order of the whole series. A careful tracing of the outcrop of this coal-seam past Quick's house and the old slope N. of the Middle Road, and again on the S. side of the basin, leads me to the conclusion that it is the same bed opened by Siveley S. of the River Road, and visible again at Inman's on the Middle Road on the opposite or N. dip. This coal is probably lifted, or rather washed, out of the basin before it reaches Behe's Pond; for the whole trough must evidently be shallower in this neighbourhood than further Eastward in virtue of the lifting influence of the two saddles, especially the S. one in the vicinity of the Green. Still further Westward, or between Behe's Creek and Nanticoke Creek, the highest coals in the basin are probably on the horizon of that of South Wilkesbarre, or perhaps a little lower. The comparatively compressed condition of the leading anticlinal, No. 17, where it bounds this part of the basin, will probably compensate for the shoaling influence of anticlinals which enter the basin from the Westward at Nanticoke, and impart the depth I have assigned to it. To the Westward of Nanticoke the basin must evidently become rapidly exhausted of its upper coals. The bluff on the S. side of the Susquehanna, at and below the mouth of Solomon's Creek, contains a bed of coal 3 feet thick at its base at the level of tow-path, which belongs evidently to a high place in the series. It is probably the tenth or eleventh coal above the conglomerate.

Tracing this basin Eastward from Wilkesbarre across the valley of Laurel Run to the upper waters of Mill Creek, we find it impossible, in the present disguised condition of the surface and unopened state of the coal-beds, to indicate the particular parts of the Coal-measures which basin out, rising Eastward at those streams. If the large coal-bed of the Baltimore Company should prove to be identical with the so-called New Haven Bed, an upper bed of which is exposed at the water-level of Mill Creek precisely on the axis of anticlinal No. 16, then indeed there will be some data for tracing this great bed of coal Eastward from that meridian in the basin before us,—that is to say, to some point higher up Mill Creek; but this sometimes asserted identity of the two coals is at present wholly without proof, for at the anticlinal exposure of the New Haven Bed no more than a 6-feet thickness of coal is exposed to view,—the statement of its being a much thicker seam resting only on rumour. It may possibly, however, be the Baltimore Company's bed, if it really does possess the alleged size of 11 feet, and if there occurs a flat anticlinal in the basin between this New Haven opening and the Easternmost tracing of the Baltimore Company's outcrop on Laurel Run. Not pretending to conjecture what the true state of things may be, I content myself with throwing out these hints for the guidance of those who may wish to pursue the exploration. I must observe, however, that I have traced the Baltimore Company's Coal from the Old Mine to Laurel Run, and thence more vaguely E. 15° N. to a point half a mile S. of the coal on Mill Creek, and have come to the conclusion that the coal on Mill Creek at New Haven is not the Baltimore Coal, but a higher one.

There is probably an axis S. of the outcrop of the Baltimore Company's Coal on Mill Creek, the effect of which must be to swing it round and place the next North-dipping outcrop considerably further N. when we trace it Eastward, and such must be its position on Thomas's

Land or Gardner's Creek. But even this will not bring it out to the level of the New Haven Coal.

Anticlinal Belt No. XVII.—The S. limit of the broad and deep river-basin which I have been describing, is formed rather by a chain of three anticlinal axes than by one continuous wave. The middle and Western links of this chain are very possibly one axis ; though unable at present to trace them into each other, I abstain from pronouncing on their identity, notwithstanding their lying nearly in one line. Between the Eastern and middle links, on the contrary, there is no such seeming connection ; the E. axis, that of the Baltimore Company's Old Mine, lying several hundred feet to the S. of the prolongation of the middle axis, or that seen at the junction of Market Street and the Eastern Turnpike. Tracing these three segments of the anticlinal belt severally, I commence with that which is most East.

Anticlinal No. XVII. *East, or that of the Baltimore Company's Old Mine.*—This anticlinal axis, the most Southern well-developed flexure of the district S. of Laurel Run, is distinctly discernible on both sides of that stream, about two miles above its mouth, and about half a mile N. of the outcropping of the Seral conglomerate in the bed of the stream. From the point thus indicated, the axis pursues a straight course W. along the S. side of the broad hill which carries the outcrop of the Baltimore Company's great bed, at its N. base, to the open workings of the old mine. At this last-named spot the very summit of the anticlinal wave is visible in the arching of the bottom slates of the great coal-bed, where the upper stream of Coal Brook crosses it. To the W. of this point, the coal-bed, here naked at the axis, is quickly saddled over by its covering strata, and the gradual subsidence of the anticlinal in that direction places the summit of the wave in the coal at a lower and lower level as it runs on and enters the mines and lands of the Black Diamond Company. It is impossible to say at present how far in the same direction this flexure actually prolongs itself ; but as the mining in its vicinity is actively advancing, the day is not remote when its W. limit will be known.

There are several subordinate rolls or trivial flexures on the N. slope of this main anticlinal of the Baltimore Company's basin ; but these, though they disturb to a small extent the working of the coal, are practically too unimportant to demand any specific notice.

This axis is nowhere one of steep curvature of the strata. Its S. dips are very gentle, being nearly flat, and its N. dips, or those into the river or Baltimore Company's basin, nowhere exceed 30°. In the old mine at the outcrop, the dip is much less than this, in but few places exceeding 10° or 15°.

Coals lifted out by the Axis.—Of the coals elevated to the surface by this anticlinal, little need be added to the statement already made respecting the outcropping of the great Baltimore seam just at the axis S. of the old mine. With the W. dip of the anticlinal, the next higher coals saddle it under cover as it declines before leaving the Baltimore Company's land, and these superior coal-beds are cut in that Company's shaft on the N. slope of the anticlinal wave. They will be more specially described in our account of this colliery.

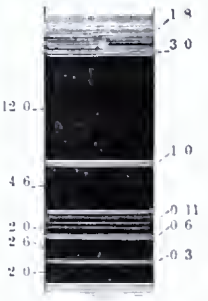


FIG. 283.—Baltimore Bed at Old Mine, S.E. of Wilkesbarre.

The great *Baltimore Bed* is mined—

1. At the Wilkesbarre Company's new mines by a slope on its N. dip.
2. At the Wilkesbarre Company's old mines (the Blackman Mines) on the N. dip of a second basin N. of the mountain, where it is worked by a slope.

3. It *has* been worked by Maffit by drifts, and a slope at the bed of a creek about 1000 feet E. of the Wilkesbarre old mines, where the N. dip is very gentle.

4. By Laning in numerous water-level drifts, S.E. of Wilkesbarre, about 1¼ miles E. of the Easton Turnpike, where the dip is N.

5. At the Black Diamond Colliery in a tunnel or shaft, &c. S. of Wilkesbarre, and also by Mordecai at the same place.

6. By the Baltimore Company at their mines in a tunnel, shaft, and in numerous drifts and open cuts.—(See the Frontispiece to this volume; also the interior view of the Baltimore Company's Old Mine.)

Anticlinal No. XVII. *Middle, or that S. of Behe's Pond.*—We come now to the middle link of the belt bounding the river-basin. It is a leading anticlinal of very considerable length, and manifests itself quite conspicuously in the features of the surface. It follows the N. brow and sometimes the crest of the broad belt of hills which separates the immediate plane of Wilkesbarre from the valley of the E. Branch of Solomon's Creek, crossing which it ranges in a very nearly straight course to the valley of Behe's Creek, a little S. of Behe's Pond. W. of this last intersection, we fail to trace it for a mile or more across the E. branch of Butler's Creek, notwithstanding its coincidence in direction with an axis which appears W. of the further of those streams, and which I have designated Anticlinal No. XVII. W. The probability is, that the two axes are one and continuous, and that a slight curve in their course is all that breaks their strictly linear prolongation; but the disguised state of the surface, due to a deep covering of drift, frustrates every attempt at actually tracing their connection, which only mining can bring to light. To define the middle axis more closely: It is seen in full development on the lane leading from the Tamaqua Turnpike to S. Wilkesbarre, about 600 feet N.W. of the turnpike; it passes the turnpike itself just S. of the elbow which this makes near the new brick building, E. of which we may follow it in a straight course till we detect its dips in the brow of the hill at the descent of the Easton Turnpike, a little N. of the junction of this with Market Street in Wilkesbarre. It probably ceases within half a mile E. of the Easton Road, for we find no evidences of it to the N. of the Black Diamond shaft, in the position which it ought to occupy.

W. of the lane where we first took it up, it manifests itself in the summit of the large swelling hill which points down towards Solomon's Creek, near the mouth of its E. branch, and we may recognise the flexure again in the lane beyond this creek leading N. from Solomon's Gap. The anticlinal is next well exposed on the middle or Newport Road, near the mouth of the next lane leading S. to the Back Road. In this neighbourhood the effects of the carving of the surface by powerful denuding waters, is conspicuously seen on the two flanks of the axis, in a double line of escarpments or sharp sandstone ledges. We may again detect the passage of the axis on the next lane to the W., or that which leads N. from Downing's, on the Newport Road, to the green on the River Road; and we catch its two dips once more to the S. of Behe's Pond, in the two hills which bound the smooth little anticlinal valley, situated a few hundred feet to the S.W. of that sheet of water. Beyond this we lose it under the deep covering of drift which conceals the strata both E. and W. of Butler's Creek. But almost in the same line we detect, as we approach the S. Branch of Butler's Creek, an anticlinal dipping of the rocks continuously traceable into the long straight axis, or portion of this same axis, which has been entitled No. 17 W.

Throughout its course, from the Turnpike S. of Wilkesbarre to the vicinity of Behe's Pond, this straight and regular anticlinal is distinguished by comparatively gentle dips; the N. ones, near the arch, not exceeding 10° or 15°, and the S. ones nowhere surpassing about 25° or 30°.

A 7-feet coal-bed has been penetrated in a well near the axis on a N. dip near the N. end of the straight street leading out from Wilkesbarre to the Easton Road, and a bed probably the same has been partially explored, on or very near the axis on Mr Ross's farm, near the S. brow of the Hill, in a direction nearly W. of the Schoolhouse. That this coal holds a high place in the series is very obvious from the relation of this axis to the outcrop of the Baltimore Vein. It is very probably the 10th Coal of the Solomon's Creek group—that, namely, which outcrops in the bed of Sugar Creek, a little above its mouth.

On the Whitehaven Turnpike the measures exposed on this axis appear to be those which separate this 10th Coal, which is not there brought out to day, from the overlying 11th, or that of the Basin next to Wilkesbarre. We meet with the same 11th Coal on the lane leading from Solomon's Gap, N.W. to the River Road; it is parted into two outcrops at this anticlinal, the more Northern one being just on the brow of the steep South-sloping hill facing Solomon's Creek. What the coal is, which this axis causes to outcrop on the Middle Road W. of Inman's, is a question we have not yet solved; but it is probably the 11th, or a still higher seam.

Within the basin lying N. of the anticlinal thus described, there occurs in the Whitehaven Turnpike a small subordinate flexure about 500 feet from it, which lifts out the coal which we have designated as the 11th, and seems not to place it back again under any cover of strata before the main axis elevates rocks which are yet a little lower in the series. The range of this feeble flexure E. and W. seems to be very limited.

Strata exposed along the Anticlinal.—The rocks and coal-beds lifted to the surface and denuded along this anticlinal axis are manifestly those which next overlie the Baltimore Company's great vein; in other words, they constitute the group next beneath the S. Wilkesbarre series. The reader will inspect advantageously the cross sections (Plate V.) which show this axis on the Easton Turnpike, and again on the lane leading N. from Solomon's Gap. N. of the Baltimore Company's main anticlinal, the whole way to the Back Road, we encounter no reversal of the dip in the district E. of Coal Brook; and in this space we recognise, as overlying the Baltimore Bed, three or perhaps four other coals of lesser size: two of these are known coals, visible at the Baltimore Company's Shaft. It is plain, therefore, that neither Anticlinal XVII. Middle, nor the little flexure N. of it, have any existence so far towards the E.

Anticlinal No. XVII., *W.*—As already intimated, this anticlinal—a probable prolongation of that just described—shows itself first a little E. of the S. Branch of Butler's Creek, crossing which, we may trace it in the topography, and likewise by occasional visible dips, to Fairchild's Lane, or that S. of Nanticoke, where the axis is well exposed close to the right-angled turn or offset in the lane. Beyond this point we lose it for half a mile as it passes the valley of Lee's Creek, but we meet it again N. of the Nanticoke and Newport Centre Road, and may trace it thence for at least three miles continuously, until it flattens away high on the S. slope of the River Mountain. In this Western part of its course it runs just at the Northern base of the hill or table-land, N.W. of Newport Centre, and, crossing the middle Nanticoke Creek, it follows the N. side of the same hill, prolonged till it enters the narrow valley occupied by the Southern tributaries of the N. Nanticoke Stream, beyond which we soon lose it in the Mountain.

The anticlinal, or section of the Anticlinal No. XVII., is characterised by a considerably greater steepness in its two sets of dips, than belongs to the middle section. Near the S. Branch of Butler's Creek both dips amount to 40°; at Fairchild's Lane, the N. dip is 40° and the S. 30°. E. of Newport Centre the S. dip is again 40°; but W. of this point it flattens to an average inclination of 20°—while the N. dip increases until, in the district between the North and Middle branches of Nanticoke Creek, it amounts in some places to a steepness of 70°.

Strata brought to light along this Axis.—Almost nothing has been done to develop the coal along the line of this anticlinal, and I can only be guided by general considerations in stating what Coal-measures the axis appears to elevate to the surface; nevertheless, a careful study of the ground from the N. side of the river basin to this axis on Fairchild's Lane, on the Nanticoke and Newport Road, and in Nanticoke Creek, has satisfied me that the saddle, in that vicinity at least, throws out none but Coal-measures very high in the series. In proof of this I would appeal to the very long succession of South-dipping strata, extending from Lee's large mine to within a very few hundred feet of the axis; to the extensive sequence of coals embraced in those strata, and to the narrowness and comparative flatness of the anticlinal, wherever it is exposed in this quarter. W. of Newport Centre the rise of the anticlinal line, and the general lifting up of the whole coalfield, causes a rather rapid cutting out of the strata in the line of the axis; but as it runs for nearly four miles from Fairchild's Lane to where it flattens in the flank of the mountain, it is obvious that there is ample space for a gradual throwing out of a thick succession of Coal-measures.

Basin No. XVIII. *and its Undulations.*—We pass now to the *middle* synclinal belt of the Wilkesbarre, Nanticoke, and Shickshinny District. This is not a simple trough, but in every part of its length it is undulated by one or more anticlinal waves. Its N. boundary is, of course, the anticlinal belt No. XVII, which we have just been tracing. Its S. boundary, or that which divides it from the basin at the foot of the mountain, is another broken line of anticlinal elevations of the strata, consisting of two main anticlinals, which are approximately in line with each other; the Eastern one indicated on the map as Axis No. XIX. E.; the more Western one as Axis No. XIX. W. The more precise description of these bounding anticlinals is reserved for the next division of this Chapter, our present topic being the structure of Basin 18, its undulations, and its Coal-measures.

Course of the Synclinal Axis of Basin No. XVIII.—Commencing with its Eastern end, we take up this Basin in the neighbourhood of Laurel Run, between the Mountain and Anticlinal No. XVII. E.; and following the valley Westward, we find ourselves behind, or S. of the Baltimore Company's Old Mine and axis, in the E. end of a wide shallow trough of the Big Baltimore Coal-bed. Pursuing the centre of this trough Westward, it takes us across the Easton Turnpike a little N. of where this crosses the East Branch of Solomon's Creek, and carries us over the Tamaqua Road about the same short distance S. of the same stream, or past the N. edge of the village of Newtown. The synclinal keel of the basin next crosses Solomon's Creek, several hundred feet N. of the mouth of Sugar Creek, being visible on the lane leading N.W. towards the canal. Following it through the hills, we meet it distinctly shown in the dipping of the strata on the next cross-road; and further forward we find it on the main Newport Road, in the neighbourhood of Ruggle's Creek. Once more we detect it on the cross-lane which passes by Behe's Pond, where it ranges about 600 feet to the N. of the Newport Road. Again we meet it crossing both branches of Butler's Creek, 800 or 900 feet N. of the Newport Road, and we find it on Fairchild's Lane, leading to Nanticoke, some 1200 feet from the road. W. of this, after crossing Lee's Creek, the synclinal belt of the basin divides or forks in consequence of the introduction of a W. anticlinal axis—anticlinal of basin 18; and the synclinal line most nearly in prolongation of that we have been tracing, runs on crossing the Dodson Schoolhouse Lane, some 1300 feet S. of the Newport Road, beyond which it gradually fades, until it ceases to be traceable beyond half a mile W. of Newport Centre. It does not reach Vendermark's Hill; but another synclinal line or basin 200 or 300 feet S. of it in position, commencing S.W. of Newport Centre, passes through the hollow of that hill, and a little N. of Fitzgerald's Corner.

The S. Branch of the synclinal, taking this up W. of Fairchild's Lane, crosses the Dodson Schoolhouse Lane about 1200 feet N. of the S. Newport Road, and from this point may be followed along the hills and across the lanes which go N. over them, till we meet it in the point of the spur-shaped Hill, intersected by the S. Branch of Nanticoke Creek, where it turns N. Thence it follows the summit of this ridge, which distinctly exhibits the basin structure nearly as far W. as the lane leading S. from Sorber's.

Strata embraced in the Central or Synclinal Portion of Basin No. 18.—We have seen that just S. of the Baltimore Company's old mine, this basin lifts out that part of the Coal-measures which includes the great Baltimore Bed. From this point W. as far as the Baltimore Bed, it retains its integrity, though at what distance it breaks up or loses this is not at present ascertainable; the basin carries that coal-seam, and the group of coals next over it. It is quite obvious that in the vicinity of Solomon's Creek, and, indeed, throughout its course, probably as far as Lee's Branch of Nanticoke Creek, the Coal-measures in the centre of this trough are identical, or nearly so, with those in the deeper part of the river-basin W. of Wilkesbarre. Possibly the highest coals retained are one or two beds lower in the series than the S. Wilkesbarre or Siveley Seam. Approaching the W. waters of Nanticoke Creek, the basin forking begins to throw out the middle Coal-measure; and towards the W. end of the coal-field, as at Sorber's and further W., it can include only the lowest division of the coal-bearing strata.

The following section, which was communicated to us just before going to press, represents the strata cut by a shaft upon the lands of the Audenried Improvement Company, about a mile S. of Wilkesbarre, and within the basin we have been describing. Comparison with the general section of the strata at Wilkesbarre (page 322), which was compiled from numerous local measurements, may be interesting to show change of type, and thickness of the coal-seams and included rocks. The dip at the shaft is 11° S.

Earth and sand, 16 feet; sandstone, 40 feet; slate, 14 feet.
Coal, 10 feet; slate, 40 feet.
Coal, 6 inches; slate, 40 feet.
Coal, 6 feet; fire-clay, 10 feet; slate, 50 feet.
Coal, 1 foot 8 inches; fire-clay, 10 feet; micaceous sandstone, 21 feet; slate, 5 feet.
Coal, 5 feet; fire-clay and slate, 27 feet; micaceous sandstone, 32 feet.
Coal (Baltimore bed?), 7 feet; fire-clay, 3 feet; black rock, 57 feet.
Coal, 5 feet; micaceous sandstone, 15 feet.

A drill hole, extended 38 feet below the bottom of the shaft, cut two thin seams of coal.

Anticlinals included in Basin No. 18.—There are at least seven independent anticlinal flexures of the strata detected by me in the general synclinal belt, all of them exerting an important influence in the distribution of the coal, and destined to control, more or less, all the future mining operations within their neighbourhood. I proceed to trace these in detail.

Anticlinal A *of Basin* 18.—The first or most Eastern anticlinal which we encounter lies S. of the main synclinal tract of the Basin, at a distance of not more than 1200 feet N. of the leading anticlinal No. XIX. E. It is a comparatively gentle flexure, originating W. of the Easton Turnpike, passing between the N. of the three sub-basins of the Wilkesbarre Company's mine and the Baltimore or main basin N. of them, and crossing that Company's lane at the White House and the Tamaqua Turnpike, a thousand feet S. of the village of Newtown. We lose this axis for a distance of about one-third of a mile as it passes under the drift-covered valley of Solomon's and Sugar creeks; but we recover it again W. of Sugar Creek, dividing two escarpments in the hill, which extends thence towards Miller's late residence on the cross-road next W.; but in this vicinity the strata are much obscured by drift, even on the summits of the hills, and it is impossible to trace the axis even up to that cross-road. The indications are, that it ceases E. of it.

This anticlinal appears to be one of rather gentle flexure throughout the E. half of its length, where it passes through the Wilkesbarre Company's lands; but W. of Sugar Creek its N. dips are very steep. Its S. dips are everywhere the gentlest.

Strata visible near the Axis.—Like the Anticlinals Nos. XVII. and XIX. adjoining it, this flexure seems to come off obliquely from the base or flank of the S. or Little Wilkesbarre Mountain, and to decline in level as it ranges W. In virtue of this subsidence, it is gradually in its progress overarched by higher and higher coals. *First,* The Great Baltimore Bed saddles the axis just E. of the Wilkesbarre Company's mines, and is under a good covering of strata from this point of its saddling W. South of Newtown, one of the lower of the middle group of coals, or of the set next over the Baltimore Bed, laps over the axis near the Tamaqua Turnpike, and a coal, probably the same in the series, which was opened just N. of Sugar Creek, above its mouth, closes over the axis a few hundred yards still further W. This is one of two coals below the Newtown Bed, and is probably about the third below the S. Wilkesbarre seam, or Siveley's. The basin made by this axis A and the main axis, No. XIX. E., will be spoken of in our description of this last-named anticlinal.

Anticlinal B *of Basin* 18.—Next in position W., is a still feebler and shorter anticlinal flexure, probably not more than a mile and a half in length, lying also to the S. of the main synclinal axis of the Basin. Our first clear recognition of this feeble wave in the strata is on the cross-road running S. from near Inman's to the S. back road, only 300 or 400 feet N. of J. Miller's old residence. From this point W. it is much obscured by drift, but we recover it again S. of the main Newport Road, in the first hill S. of Ruggle's Creek, and may detect it crossing this road quite obliquely, just at the schoolhouse on the summit of the hill. From this point of intersection we can trace it gradually flattening and fading, for about one-fourth of a mile, when it disappears almost directly in the general synclinal line of the basin. At the next series of exposures, namely, on the lane just W. of Behe's Creek, we have the fullest evidence that it has disappeared.

Throughout its course, this flexure is a very flat or gentle one, yet it may probably influence the future mining of the district sufficiently to make this notice of it important.

Strata exposed near this Anticlinal.—It is in the vicinity of this anticlinal of the Schoolhouse, but in the basin N. of it, or in the main synclinal, that a Red-Ash coal-bed, 6 feet thick, has been opened, and mined to some extent on the lands of John Hoover. This coal evidently occupies a high position in the series, and its proximity to the little anticlinal proves how trivial the effect of this latter has been in causing the denudation of the upper Coal-measures.

Anticlinal c *of Basin* 18.—The third anticlinal in this basin going W., is a very regular and straight one, running nearly parallel with the Middle or Newport Road, at a short distance S. of it, from Behe's Creek to the mouth of Fairchild's Road, leading N. to Nanticoke. Its length, from its E. point of origin, which is just E. of Behe's Creek, to the spot where we lose it N. of A. Line's, is about·3 miles; and its average distance from the main Anticlinal XIX. W., which lies S. of it, and makes with it a regular subordinate basin, is from 1000 to 1100 feet. This axis is accompanied along its E. half by unusually steep dips; but towards its W. termination the flexure becomes gentler, and the inclination of the rocks near it does not exceed 30°. It ends E. in a mere twitch or steep rumple in the broad belt of steeply North-dipping strata thrown off by Axis XIX. W.; but W. it appears to expire in the more usual manner by gradually flattening down. Throughout its course the axis may be readily traced by the marked impression of the anticlinal arching of the strata, upon the topography or the configuration of the surface.

Very little can be stated specifically in regard to the coal-beds which this anticlinal lifts and exposes at the surface, further than that they are those which lie next subjacent to the high Red-Ash seams before spoken of as opened on John Hoover's land, near the Schoolhouse on the Middle Road. They belong, therefore, to that division of the Coal-measures which is so generally lifted to the surface by the anticlinals which lie centrally in the Wilkesbarre and Nanticoke District, or which, in other words, traverse the chain of hills called the Hog Back—coals which I have designated as the middle group of the series, above the large lower White-Ash beds of the border of the basin, but beneath the two or three highest seams, which only occur in the synclinal knobs and table-lands.

Anticlinal D *of Basin* 18, *or that of Newport Centre.*—We come next in order to a much more conspicuous anticlinal wave. This, indeed, in the more central part of its course, is a double or complex flexure, and there, in the vicinity of Newport Centre, it is accompanied by very steep and abrupt dips, and apparently by some dislocation of the rocks. We first detect this anticlinal as a single and rather gentle flexure, on the cross road running S. from Nanticoke, only a few hundred feet N. of the late Solomon Fairchild's private lane; but the undulation displays itself in more complex and prominent features as it approaches Newport Centre, especially where it is crossed by the Dodson Schoolhouse Lane, and by the Nanticoke and Newport Road. Beyond the little village of Newport, the S. axis, or that of Fairchild's Farm, seems to disappear in descending Foster's Hollow, towards Hollenback's old mill; while the N. flexure, crossing just N. of the village, runs on to take the S. brow of the hill next N. of the Middle Nanticoke Creek, and in this line of prolongation it finally flattens away somewhere on the slope of the River Mountain.

A third much feebler flexure accompanies these two axes of this compound anticlinal wave, at a distance of some 300 feet S. of the Southernmost of the two chief axes of this compound anticlinal at Newport Centre.

On the Dodson Schoolhouse Lane, and near Newport village, the S. dips of the Southern of the two axes, and the N. dips of the Northern, are extremely steep; while the basin, not more than 200 or 300 feet broad, which divides them, is in the same proportion flat or shallow.

Strata exposed by the Anticlinal.—Two or three coal-openings occur adjacent to this anticlinal on the W., especially those of Newport Centre. One of these is on the S. side of the axis N. of the middle branch of Nanticoke Creek, and nearly opposite Fitzgerald's Corner; but what place in the series this or the other coals occupy, it is not possible, in the present undeveloped state of the district, to ascertain.

Anticlinal E *of Basin* 18, *or that of the Fitzgerald's Schoolhouse.*—Another anticlinal flexure of considerable length, possibly as long as the preceding, ranges along the S. side of the general Basin, No. 18, in a direction not strictly parallel to the bounding Axis, No. XIX. W., but converging gently towards it on going W. This axis, throughout the central part of its range, especially near to where it is intersected by the S. Branch of Nanticoke Creek, or S. of Vendermark's Mill, is characterised by very steep dips, both legs of the arch dipping at as high an angle as 80°, and exposing bold ribs of the coarse conglomeritic sandstones in those points where the softer strata have been most denuded. We first take up this axis on the road running S.W. from Newport Centre to the Methodist Meeting-house, about midway between those two points. Here the N. dip is but 5°, and the S. dip 20°. Tracing the axis to the cross road next E. of S. Nanticoke Creek, we can follow it thence along the valley of a Northern tributary of that stream at the N. foot of the hill, till it passes a little N. of the Fitzgerald Schoolhouse, beyond which, as it approaches the lane running S. from Sorber's, the dips and impression of the axis on the topography become less distinct.

Strata exposed.—Besides the bold ribs of conglomeritic sandstone developed at this axis, two or three outcrops of coal are visible near it; but I cannot say precisely what beds these are, nor can any one determine till the region is more explored by mining. They are evidently, however, members of the middle coal series of the basin.

Anticlinal F *of Basin* 18.—Far W. in the basin, and nearly centrally placed in it as respects its bounding anticlinals, is a gentle flexure some 2 miles or more in length, running from the valley of the middle branch of Nanticoke a few hundred feet N. of George Sorber's house, and thence to the very head of the S. Branch of Nanticoke, or the water-shed between that stream and the N. Branch of Black Creek, a point immediately N. of the road through the basin. A small coal-seam 2 or 3 feet thick has been opened on the S. dip of this axis, a little S. of the road near the water-shed here mentioned.

Wherever the dips belonging to this flexure have been detected, they do not exceed 15° or 20°.

Anticlinal G *of Basin* 18.—About 1400 feet N. of Sorber's, and therefore some 700 or 800 feet N. of Axis E, occurs another, which we call G. This is apparently a short flexure, and is too obscure and unimportant to merit a closer tracing.

Anticlinal H *of Basin* 18.—In the W. extremity of the basin there is another short anticlinal lying about 700 feet N. of the coal-drift, known as Colt's Coal. It is in fact this arch which contains Colt's coal, which, at the drift mouth, dips as gently as 5° S., and this would seem to be the flatness of the S. side of this axis generally. On the N. side of the anticlinal the dips are steeper, being as much as 25°.

The coal called Colt's probably emerges to the day nearer to the axis than at the spot where it has been mined; but at that point the bed has been entered by a lower or valley outcrop, the result of denudation, leaving a perpendicular cliff of sandstone, at the base of which the coal appears dipping with the slope of the hill.

Anticlinal Range, No. XIX., *or that separating Basin* 18 *from Basin* 19.—It has been already stated that this anticlinal belt consists of two principal flexures, the E. one designated as No. XIX. E., and the W. as No. XIX. W., and that these are separated in the middle part of the belt by a blank space, where neither is at present visible. Let us now define them with more precision, and indicate their effects upon the strata.

No. XIX. *East.*—Our first clear indications of this axis are at its intersection with the Easton Turnpike, which it crosses only a few hundred feet N. of the Toll-gate, and N. of the foot of the mountain. E. of this point it is too imperfectly traceable at present to admit of delineation; but W. we may follow it in a chain of anticlinals so nearly in its prolongation as fitly to be considered one with it for a distance of some 3 miles, or to a point half a mile W. of Sugar Creek. The Toll-gate Saddle or E. division of the axis is traceable to the Wilkesbarre Company's mines, where it is the axis which separates their middle or smallest basin from the third or N. one of those which the company is now working, or the axis upon which the underground steam-engine is seated.

Directly in the line of the anticlinal is a beautifully exposed flexure, in a cut of the Lehigh and Susquehanna Railroad, at the foot of plane No. 3, at Solomon's Gap; and this flexure I am disposed to consider identical with that just mentioned, as dividing the Wilkesbarre Company's second and third basins. This axis of the foot of the plane we can again recognise half a mile W. of Solomon's Creek, in the sharp sandstone crests of the hills, at a distance of about 1500 feet N. of where Sugar Creek intersects the Back Road; but approaching the cross-road next W., we fail to trace the further progress of the anticlinal for some distance, in consequence of the broad sheet of drift which there conceals all the outcrops of the rocks. We must pass, in fact, a blank space of more than a mile and a half, before we gain unequivocal traces of the anticlinal which lies nearly in its prolongation, and which is designated No. XIX. West.

The amount of flexure in this anticlinal wave is nowhere very steep in its E. portion; but in the vicinity of Solomon's Creek, and W. of Sugar Creek, the arching is much greater. On the Easton Turnpike at the toll-gate, the dips are very gentle, and they continue thus to the Wilkesbarre Company's mines; but at the foot of plane No. 3, at Solomon's Gap, the S. dip is as steep as 45°, while the N. leg of the arch inclines at 60°.

Coal exposed along this Anticlinal.—At the Easton Turnpike this flexure just lifts to the surface the rocks which next underlie the Little Toll-Gate seam, or the second coal below the Great Baltimore Bed; but the W. subsidence of the axis-line permits higher strata successively to oversaddle it, until, at the Wilkesbarre Company's workings, the Baltimore seam itself closes over it, passing out from the second or N. Branch of Basin 19 into the third or S. trough of Basin 18; and again by the continuance of this W. subsidence, still higher coals in the series—namely, the 10-feet and 4-feet, or the second and third coals above the Baltimore Bed—are permitted to arch themselves at the axis. These are beautifully exposed in the regular anticlinal

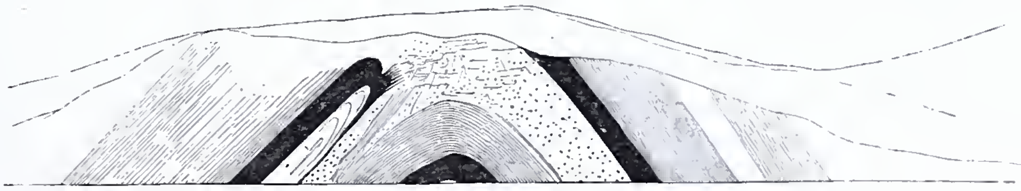


FIG. 284.—Section of Anticlinal Flexure No. XIX., near the foot of the lower inclined plane, Solomon's Gap, looking W.

arch of the railroad cut, near the foot of the plane. (See our illustration of this cut, Fig. 284.) To the W. of Sugar Creek a coal still above these shows itself outcropping under the sandstone crests which there border the anticlinal axis.

At the arching of the coals in the railroad cut we behold a curious fault, with redoubling of the Second Coal, implying a N. sliding of the strata while in the act of bending. (See Fig. 284.)

Anticlinal No. XIX. West, or that of the Dodson Schoolhouse and S. Nanticoke Creek.—We have now to consider by far the longest continuous division of this anticlinal range. The first exhibition of this remarkably straight axis is to be met with a short distance W. of Behe's Creek, on the lane leading from the Middle to the Back Road, which it crosses about one-fourth of a mile N. of the latter. Crossing Leuder Creek, we trace this axis thence continuously through Leuder's Hill and across his lane, and meet it again on the Leutze Gap Road, a few hundred feet N. of the thick Stiver Coal-bed; thence we follow it to the Dodson Schoolhouse, and beyond this, by the base of the bluff hill N. of the main road, until it obliquely enters this hill, and stretches on to the S. Branch of Nanticoke Creek. In this part of its course it crosses the lane leading from the S. road up to Newport Centre, at a distance of some 1200 feet N. of the main S. road; and we detect it again just N. of the new Methodist Meeting-house, from which point we trace it readily, by the features of the surface, to the intersection of the middle road of the valley, with the S. Branch of Nanticoke Creek, and can follow it thence up the narrow valley of that stream to where this is crossed by the lane leading S. from Sorber's. We may pursue it, indeed, still further W., through the broad flat hill S.W. of Sorber's, to a knob which fronts the N. Branch of Black Creek, nearly opposite the outcrop of the large coal-seam known as Colt's. In all this course of about 9 miles, this axis observes an extraordinary straightness and regularity. It is a flexure of the normal type; that is to say, its S. dips are gentler than its N. ones, these latter being remarkably steep, especially between Leuder Creek and the Dodson Schoolhouse.

Strata elevated by this Anticlinal.—No very positive data at present exist for ascertaining precisely what division of the coal-series is brought to the surface by this axis in the different portions of its length; but the carefully-measured section near Leuder Creek, and other systematic explorations in the vicinity, lead me to the inference that, in this E. part of its course at least, it fails to lift out any but the highest coals of the district. There are probably at least twelve coal-beds beneath the saddle where it crosses Leuder Creek; nor do I suppose that this *suite* of coals is much reduced until we approach the Stiver opening, which, being a coal of unusual magnitude, is probably somewhere near the horizon of the Baltimore Bed, or five or six coals above the bottom. Approaching the S. Branch of Nanticoke Creek, probably still lower coals throw themselves out, though the flattening of the axis in its W. range, and its slight retreat from the S. edge of the coal-field, may compensate for the general Westward rise of all the strata. It is therefore quite possible that the large bed called Colt's is on the same horizon with the thick Stiver seam.

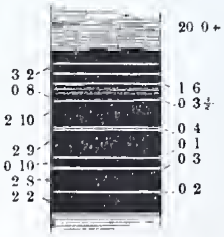


Fig. 285.—Stiver's Bed.

In the annexed woodcut the reader has a representation of the characters and dimensions of the Stiver Coal.

Basin No. 19, or that of the N. Foot of the Little Mountain.—This, the third, or most Southern large synclinal trough of the district, is a very straight belt of Coal-measures, undulated, however, by a number of anticlinal waves, disturbing the distribution of its coal-beds from that perfect symmetry of flexure which they would otherwise possess. So numerous are these intruding anticlinal waves,—with nine or ten of which we are already acquainted, while probably several others of lesser magnitude remain undeveloped,—that it would be fruitless to attempt at this time any tracing of a general synclinal axis centrally along the belt; nor is it probable, indeed, that such exists. It must suffice, therefore, in attempting to exhibit all that has been brought to light respecting the structure of this tract, to indicate the anticlinals which it contains, and the effects which these may be judged to have upon the outcropping and distribution of the coal-beds.

Anticlinal A, *Basin* 19, *or that of Solomon's Gap.*—To commence as usual with the most Eastward in the basin. This subordinate flexure, traceable for perhaps a mile in length, crosses Plane No. 3 in Solomon's Gap, two-fifths of the length of the plane above its base. Here the flexure is well exposed in a cutting on the plane, and is visible, though more obscurely, on the turnpike adjoining the railroad. Half a mile to the Westward we detect it S. of Preston's house in an old excavation.

The strata lifted by this axis on the Railroad Plane are those immediately overlying the complex lowest large coal-bed or group of coal-seams, called the 19-feet bed, only the highest layer of which indeed is laid naked by it.

This axis appears to decline gently to the Westward, and it is probable, though by no means certain, that the coal-beds affected by it at Preston's are those next above the complex 19-feet seam.

Adjacent to this flexure, and a little S. of it, is another shorter and feebler one, discernible as a roll in Ross's Mine on Solomon's Creek; but this makes no external impression, and is probably of very local influence.

Anticlinal B, *Basin* 19.—Next in our progress Westward is a very long but rather gentle anticlinal flexure, commencing near Sugar Creek, and extending beyond the Western tributary of Behe's Creek. It ranges parallel with the foot of the mountain, diverging slightly from it Westward. The position of this axis for a greater part of its length is 900 or 1000 feet S. of the Back Road. It is seen in the arch at Carey's Mine in the bed of the little brook which flows there, and we detect it again in Collins's Mine, about a mile further W. At both places the dips are of moderate steepness, the S. dip at Collins's being 20°, and the N. 30°. In Carey's Mine this axis lifts to the day a seam of coal 4 feet thick; and in Collins's Drift, the coal-bed which arches has a thickness of 8 feet, and is a higher coal. Comparing its position with those of the coals visible in the cut of Warrior Creek further W., this bed appears to be the fifth in the series of the large or workable seams above the conglomerate.

Anticlinal C, *Basin* 19.—The next anticlinal flexure within the basin which calls for notice is one which has thus far been detected only where it has been intersected by Warrior Creek on the Babb Lot, where it is well displayed on the Railroad and mining section there developed. It interrupts the general N. dip of the strata towards the centre of the basin, and turns at least five of the middle coal-seams over into a steep S. dip of 60° or 65°; the N. side of the flexure dipping 40° or 45° N.

The coal-seams which it thus causes to arch are apparently the lowest of the middle group, or those next above the horizon of the Baltimore Bed; not assuming it as certain, however, that this maintains its integrity so far to the W.

Anticlinal D, *Basin* 19, *or that of Bergman's Run.*—We come now to a sharp flexure in the strata, close to the foot of the mountain, intersected by Bergman's Run, about half a mile S. of the Tavern on the main road of the valley. This axis may possibly possess considerable length; but being close under the foot of the mountain, the strata are too much concealed for us to trace it. It is remarkable for the excessive steepness of the S. side of the flexure, the dip towards the mountain being nearly perpendicular. This posture of the strata, giving rise to a precipitous wall, causes the stream here to take a sudden leap, and form a really beautiful cascade. The N. dips from the axis are extremely gentle, even at some distance from the axis-line not exceeding 15°.

The coal-beds lifted to the day by this broken flexure are evidently very low in the Coal-measures. (See the Section at Bergman's Run or Gulick's Tavern, fig. 291.)

Anticlinal E, *Basin* 19.—N. of the last-described anticlinal commences a longer and much more conspicuous one, ranging nearly centrally in the basin. Its first traces are seen in Bergman's Run, about a thousand feet S. of the Tavern on the road, its effect being a saddle in one of the coal-beds of the stream. Here, however, the flexure is extremely gentle, neither dip exceeding 5°. Some three-fourths of a mile further W. we may discern it more distinctly, just N. of the South-dipping outcrop of a bed of coal mined to a small extent a few hundred feet S. of the road; the sandstones between this coal and the road dipping N. from the axis. A little further W. the same anticlinal, or what appears to be the same, is visible in the small mine upon the thick seam of coal called Wright's Bed, where the coal is entered S., and dips W., actually saddling over the axis.

This anticlinal, or one very nearly in its range, now crosses the road, and pursues the bed of the narrow valley traversed by the W. Branch of Lee's Creek. Here the anticlinal structure of the valley is well exhibited for a mile or more in its escarped and precipitous sides, and the opposite direction of dip of the two sets of exposed strata. How far this anticlinal is prolonged towards the W. it is hard at present to say; but it seems not to reach the obscure cross-road which extends through the forest from the inn called "Traveller's Rest" to the North Road near Sorber's.

An outcrop of coal is visible in the bed of the Anticlinal Valley, a few hundred feet N. of the main road, and another coal, known as Kocher's Opening, occurs close to the axis just S. of the same road; but nothing can be established at present regarding the places which these coals occupy, nor anything positively indeed respecting the position to be assigned to the large bed called Wright's, which may or may not be identical with the others.

Anticlinal F, *Basin* 19.—Another anticlinal, accompanied by apparently gentler dips than those which attend the preceding, appears near the main road further Westward, a few hundred feet N. of the conspicuous outcrop of coal visible on the roadside, and called Lesher's. The Westward extension of this axis has not been ascertained, but it seems not to cross the road running N. from "Traveller's Rest."

Anticlinals G *and* H, *Basin* 19.—Two other anticlinals have been detected by us within this general synclinal belt in the W. end of the coal-field; the more Southern of these occurring in the hill between the two Southern spurs of the Hog Back, and the more Northern ranging just N.

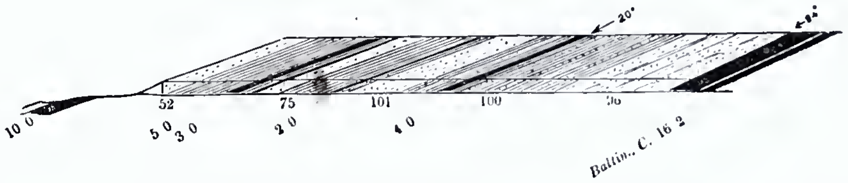
of its third and longest spur, and prolonging itself in the direction of Shickshinny. Too little is known at present of these anticlinals, or of the coal-beds disturbed by them, to enable us to trace them with more detail, or to exhibit their influence upon the strata. The approximately correct section of the district of the Hog-back is presented in the column, (see Fig. 294.)

Other flexures besides those we have now enumerated, will probably be brought to light by future mining operations within this synclinal belt, and those which have been here described will unquestionably become better known and more distinctly developed; but quite enough has been detailed concerning these and all the other discoverable undulations of the district to furnish a clue to the distribution of the many beds of valuable coal which it embraces, and to prove a useful guide to all future explorations and mining undertakings.

Distribution of the Coal in the E. End of Basin 19.—Reverting to the E. end of the general basin before us, with the view of recognising the basining-out of its Coal-measures, we may observe, by consulting the Map and the Geological section which follows the Easton Turnpike, that while the lower large coal-bed, or Jamieson's, crosses the road to basin out at some distance E. of it, between the foot of the mountain and the Anticlinal Axis No. XIX. E., the upper larger coal, or Great Baltimore Bed, is not cut by our section, but basins out or is washed away to the W. of it. This valuable layer of coal is, in fact, disposed in two basins within this belt—the larger one lying at the foot of the mountain, and heading several hundred yards W. of the Turnpike, and the lesser, a much shorter and narrower one, running only a few hundred feet E. from the Wilkesbarre Company's Main Slope. The anticlinal which divides these two Southern basins of that Company's lands ranges just S. of their slope, lifting there the rocks which immediately underlie the large Baltimore Bed; but declining to the Westward, it soon permits the coal-seam to saddle its axis; and there is reason to believe that the undulation altogether subsides within a range of perhaps half a mile towards the W. Considering it, therefore, as only a roll in the strata, I have not enumerated it among the leading anticlinals, nor given it a special designation. Its influence, however, is all-important upon the mining operations conducted within the coal estate of the Wilkesbarre Mining Company.

Lane's Tunnel, entering the S. side of this basin, penetrates to the Great Baltimore Bed, and cuts the two overlying coals, as shown in the annexed engraving.

Fig. 286.—Lane's Tunnel, E. of Solomon's Gap.



Blackman's Slope, or Slope No. 3, at the Wilkesbarre Company's Mines, is 70 yards down, and goes deep into the basin. It ends at a dip of about 30°, and the top of the slope is about 60 feet above the adit at water-level, which is now being constructed to dispense with the upper part of the slope lifts, and the return inclined plane.

This water-level adit is to be driven 45 yards through rock into the coal-bed.

Beneath the big coal in Blackman's Mine, the coals are—1st, A bed which crops out at the Toll-gate. It is a 7-feet coal, pretty good, and in tiers of 18 inches and 1 foot of coal; it is about 200 feet below the Big Bed. 2d, A coal which is 6 feet thick, and is separated by 5 feet of hard fire-clay,—Stigmaria Shale.

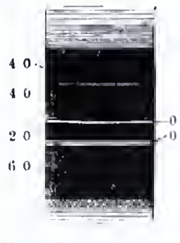


Fig. 287.—Baltimore Bed (Blackman's), E. of Breaker.

At an interval of 60 yards in the tunnel are the 3d, 4th, and 5th Coals, separated by 3 feet of slate; while the lowest of them is separated by 2 feet of slate from the big seam of coal called the Nineteen-feet Coal, but actually 14 feet thick. These three closely-adjacent beds are each 3 feet thick, and one of them yields a Brown Ash.

The Big Seam is the lowest, at present, known in this vicinity.

The bottom layer of the Lower Big Coal of the S. side of the basin at the Wilkesbarre Company's lands at Solomon's Gap is Red Ash Coal.

The coal of the Mill is regarded as the bottom tier of the Nineteen or Fourteen-feet Coal. At the Wilkesbarre Company's land the lower division of the Lower Big Coal lies just on the conglomeritic rock, with only a few inches of shale intervening.

SECTION OF THE BIG COAL.

	Feet.	Inches.		Feet.	Inches.
Coal,	1	3	Bony Coal,	0	8
Shale fire-clay,	0	0	Coal,	2	8
Slaty Coal,	2	0	Slate,	0	0
Good Coal from	8 to 9	0	Best of Coal,	4	6

The Eight-feet Rough Coal of the Baltimore Mines is much further from the main bed at the Wilkesbarre Company's Mines, being at its last S. outcrop at the foot of the mountain as much as 200 feet S. of the outcrop of the Big Coal.

At Jamieson's old opening on a 19-feet bed of coal, the signs of metamorphism are quite abundant. The coal exhibits in the direction of the strike long chunks like planks; the Bird's Eye surfaces are in this direction, an exception to the general rule. The dip is from 20° to 25° N. 30° W.

COALS IN SOLOMON'S GAP (SEE SECTION, PLATE V.)

The lowest coals of the Wyoming Coal-basin are finely exhibited at Ross's old mines in Solomon's Gap, immediately below Solomon's Falls. Here the lowest bed is worked by a drift at the Creek level. The same coal is to be seen in its entire thickness in the Railroad cut at the Red Mill. It is about 8 feet thick, with several slate-partings. Its character appears to be rough, and in some benches quite bony. The slate overlying it is about 3 feet in thickness. Its dip is about 30 to the N.N.W.

The next vein ascending is also opened by a drift at the water-level; it is about 8 feet thick, and has about 2 feet of parting-slate in its centre. The character of this seam, as well as of all the coals at this locality, is quite rough and bony. About 9 feet of slate intervene between this and the next overlying vein, which contains 3 feet of impure coal; it has not been opened at this place.

A flaggy sandstone, 10 feet thick, forms the roof of this bed, and the bottom of an 8-feet thick coal next above it is here opened by a water-level drift. It appears to lie in three or four benches; the upper of which is 2 feet thick, and is separated from the others by 3 feet of slate. The several seams here opened appear to be divisions of one and the same large bed.

At this point there would seem to be some confusion in the stratification; but by tracing the course of the fire-clay, which overlies the last-mentioned coal, it proves to be a simple though somewhat abrupt turn of the vein in the form of an anticlinal, by which it is thrown below the water-level.

The last and highest coal here opened is a 10-feet coal, with 1 foot of bottom slate. It is entered by a number of drifts at the water-level, inasmuch as its dip is but a *very* gentle one to the N. It lies in four benches of about equal thickness; the partings being quite thin. Its character, like that of the rest, seems to be rough. Without doubt, it is the so-called 19-feet vein of this region, either entire or in union with the bed below, from which it is separated by fire-clay.

I am induced to regard this as the 19-feet coal-seam, from the following considerations:—

1. It seems to lie in a position with regard to the lower conglomerate which that bed generally occupies; that is to say, we here see at least *two*, and probably *three* seams underlying it.

2. There is a considerable thickness of slate overlying it; probably as much as 50 feet. Now, by measurement in Grey and Landmesser's Tunnel, at the back end of which the 19-feet vein is known to exist, there is about the same amount of overlying slate, and I know of no vein so low in the series which has so great a thickness of roof slate.

3. Another reason is to be found in the flexures of the strata at this locality. On the inclined plane, a few hundred feet to the N. of these openings, there is a small cut at the little breaker of these mines, which exhibits a small anticlinal axis, by which the 19-feet bed would appear to be thrown some few feet above the level of the plane, and made to turn over into N. dips; and this N. dip of the vein may be traced immediately to the outcrop at the back end of Grey's Tunnel. The truth of this supposition will depend upon whether the vein here, poorly exposed in the road cut, is really the Big Ross vein; and if so, whether it is actually traceable to the outcrop S. of the tunnel. A leader or thin coal on the Railroad seems to be several feet thick in the tunnel; that they are one and the same there can be little doubt, as at both localities the same coarse flaggy sandstone, containing numerous pebbles, overlies the bed. This is an additional argument for considering the anticlinal seam as the 19-feet vein, whether it be the same as the Big Ross vein or not.

The 19-feet coal has been mined; 1, At Ross's mines, in Solomon's Gap, by water-level drifts; 2, At the back end of Grey and Landmesser's Tunnel, which was driven in 241 feet to reach it, (it dips N. at this point about 25°); 3, By an open cut on its outcrop about a quarter of a mile E. of Grey and Landmesser's shaft; 4, It has been driven to, in Jamieson's Tunnel, about half a mile E. of the shaft; 5, Also in the vicinity of the Wilkesbarre Company's new mines by a tunnel now abandoned, the so-called Blackman Tunnel; 6, By open cut and drift at Parrish's old mines, about half a mile N.E. of the Prospect Rock House.

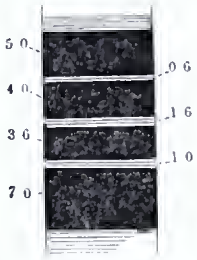


FIG. 288.—Lower Big Coal at Landmesser's, E. of Solomon's Gap.

At none of these localities is it now worked; nor is it, to my knowledge, mined anywhere on the S. side of the river. The relations of the so-called 19-feet bed, and the Baltimore seam near Solomon's Gap, are illustrated in the cut here presented of Grey and Landmesser's Tunnel. (See Fig. 289.)

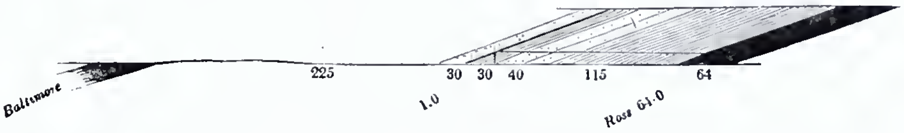


FIG. 289.—Grey and Landmesser's Tunnel, near Solomon's Gap.—1 *inch* = 200 *feet*.

DISTRICT W. OF SOLOMON'S GAP.

West of Solomon's Creek perhaps a mile, occurs a gully, upon which several coal-seams have been opened on Wright and Conyngham's land. I know no name for the ravine. The tenant was William Stapleton. Carey's Coal-bed is opened some distance up the stream.

The following section made on Carey's Run, or Sugar Creek, exposes the seams underlying the large or Baltimore Bed, and enables us to arrive at some satisfactory conclusion as to the number and thickness of the veins constituting the Coal-measures of the Wyoming Basin.

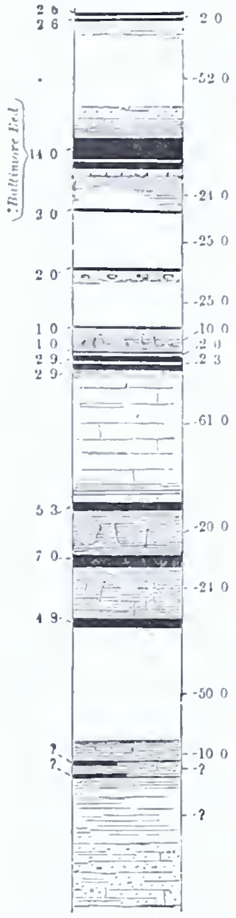


FIG. 290.—Carey's Run, 1½ mile W. of Solomon's Gap.

The first or uppermost coal seen is about 7 feet thick, consisting of two benches 2½ feet each, separated by an intervening slate 2 feet in thickness. The dip is 30° N. The W. bed is 14 feet thick, but not very well exposed, dipping 45° N. This is supposed to be identical with the Baltimore bed. The third vein is scarcely 2 feet thick; and then follows the fourth, which is about the same size; under it is a band of ore containing sulphuret of iron. The fifth bed is well exposed, forming a roll with steep dips of 50°, soon, however, rising again with a N. dip of 30°. It is about 10 feet thick, and may be thus described:—Coal, 1 foot; slate, 2 feet. Coal, 2 feet 9 inches; slate, 2 feet 3 inches. Coal, 12 feet 9 inches; bottom slate, 4 feet, full of Stigmaria; coarse sandstone, massive. This roll also repeats the overlying vein. The sixth bed dips 27° N., and is over 5 feet thick. Coal, good, 4½ feet; slate, 6 inches. Coal, 8 inches; slate, full of Stigmaria, and in its lower part large lenticular masses of iron-ore. The seventh bed dips 30° N., and is more than 7 feet thick. Coal, 5 feet; slate, 1 inch. Coal, good, 2 feet; slate (Stigmaria), 3 feet. Coal, 8 inches.

Slate intervenes between this and the next vein, the eighth, which dips 40° N.; and, as far as could be ascertained, is 5 feet thick.

The next seam, the ninth, is evidently two layers of coal, separated by a slate 4 or 5 feet thick; the dip is steep. The massive sandstone under it forms a bold ledge, over which the water falls. Steep dips continue for perhaps 70 or 100 feet, when it changes to a S. dip of 25°.

This again changes to a N. dip of 25°, the sandstone forming a rapid of 100 feet in length. The next dip is 25° S., succeeded by a dip of 30° N., forming several rapids. The conglomerate then appears dipping 40° N.

This section exhibits the rolling character of the strata, though it would be difficult to trace any one of these rolls far in either direction.

It would appear from these exposures that no less than seven seams of coal lie between the Baltimore bed and the Conglomerate, four or five of which are of sufficient thickness to be wrought. The section may serve as a guide in searching for beds along the mountain, between the outcrop of the Baltimore vein and the Conglomerate.

In that part of the valley between Solomon's Creek and the Wyoming Coal Company's railroad several mines exist. There is a coal at Inman's on the Berwick Turnpike; it is 3 feet thick, dipping 25° N.W.

Caleb Inman's bed, also 3 feet thick, is opened on the new road on a hill, near a stone bridge over Solomon's Creek. It dips 20° S.S.E., and is evidently the same bed as the preceding—a synclinal trough existing between the two openings.

On a little branch of Sugar Creek, about 800 or 1000 feet from the back road down the S. side of the valley, a coal is opened in a tunnel driven by Mr Holland of Wilkesbarre; no other coals were cut. The dip at the surface is displayed in massive sandstone N. 55-60°. A distance of 100 yards from the tunnel on Preston's land coal has been taken from the surface. The bed measures 6 feet in two benches separated by thin slate—dip. 30-35° N.

Two coals have been proved by tunnels on Preston's land. The tunnels are 115 yards asunder, and on different levels ; the same beds are cut in both. The two beds are 6 feet thick each, and are distant 120 feet in the upper tunnel. A third coal, 4 feet thick, is found over the upper coal of the upper tunnel. It lies 100 feet from the mouth ; its dip is quite flat, or even Southward ; but it rolls over, and is cut in the lower tunnel where it is faulty.

The upper 6-feet coal, and that opened near Holland's old tunnel above, are thought to be the same seam.

Continuing W. in the coal-basin there is a satisfactory exposure of the strata on the railroad of the Wyoming Coal Company about six miles from Wilkesbarre : it exhibits a series of coals overlying the great lower seam.—(See section from the Susquehanna to Warrior Path Gap, Plate VI.)

The uppermost bed of the series on the railroad of the Wyoming Coal Company was cut in a tunnel driven to it by Mr Holland ; it is 6-8 feet thick, and dips about 20 N°. ; the same bed is opened 100 yards farther W., and still farther a slope was sunk 100 feet upon it.

Following the railroad up the creek, we have in the creek and the cuttings on the Babb lands fine exposures of coal, six or seven in number. They are shown in our section. The average thickness of these coals does not exceed 4 feet. Several of the beds are repeated by a sharp anticlinal, which from a dip of 40° or 45° N. turns them over to S. dips of 60°. Near this the railroad branches, one fork going to an old tunnel driven by Mr Holland to meet a large coal, the other to the Warrior Path Gap of the Little Mountain. Our section follows this, and exhibits several fine beds of coal in the notch. The first of these is a compound bed opened by a drift on Mr Rummage's land. The upper portion is 6 feet thick, the lower 9, separated from the former by 18 inches of slate. The dip is 30° N. S. of this 100 feet horizontally a second bed has been opened ; it is 9 feet thick. A few hundred feet further S. a third bed, capped by pea-conglomerate, and resting on thin-bedded sandstone, has been proved. It is said to measure 12 feet. This is within 100 yards of Collins's Sawmill, behind which the Seral conglomerate rises from the water-level at an angle of 40°. In the conglomerate a thin coal of 3 inches has been found.

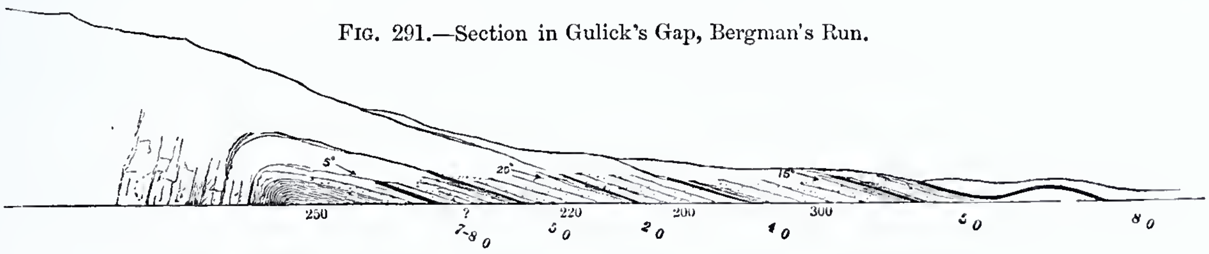


Fig. 291.—Section in Gulick's Gap, Bergman's Run.

Our section of the Gap in the Little Mountain at the back of *Gulick's Tavern* (see Fig. 291), about nine miles from Wilkesbarre, displays several coals. The uppermost of these is gently arched above water-level : it is proved to be fully 8 feet thick. Below this is a bed of bone coal and slate, containing impressions of Lepidodendron, 5 feet thick. The third coal is 4 feet thick, and has been mined to a limited extent. It dips N. 7° to 10°. The next bed is thin, not exceeding 18 inches. It is overlaid by slate containing iron ore. Below this is a workable coal 7 or 8 feet thick. Its quality is fair, and it has been mined. Something over 100 yards S. of this, at the falls of the creek, on a nearly perpendicular Southern dip, a coal was seen which, including bony coal and slate, measured 11 feet. It is all more or less squeezed and faulty. The lower 6-feet are the best. This coal is not represented in the section.

Wright's coal, three-fourths of a mile W. of Gulick's, is a large bed, having 10 feet of coal in all, thus:—

Slate and Coal, 3 feet; Bony Coal, 2 feet; Good Coal, 8 feet.

It dips W., turning round with the dying-out of the anti-axis from the E. Its cover is slate, &c. It is in the same hill with South-dipping coal, 300 yards E. of it. This S. dip of coal is not all seen; it looks like the West-dipping bed, and dips S. 15°. On the N. slope of the same ridge the dip is 30° N.

I am in doubt whether the denuded axis W. of Wright's coal, W. of Gulick's, is not a little N. of the axis of the coal itself.

At Fitzgerald's on the Schoolhouse No. 3, there is a coal-bed 7 feet thick, dipping N. 30°. Under this there is said to be one 14 feet thick. On John Schleppy's Farm, in the same valley of the N. Branch of the Nanticoke Coal, a little W. of the Schoolhouse, a coal-bed lies in the hill, and dips S. 30°. It is 7 feet or more thick; a boring of 8 feet did not go entirely through it.

At Schleppy's, one-fourth of a mile W. of the cross connecting-road, and adjoining Meyer's, there are 3 coals opened. One at the road, with N. dip, is 7 feet thick; one in the ravine about 5 feet, with steep N. dip; a third on the N. side of the basin 7 feet, and dips S.

John Hoover, near the Newport Road, has a Red Ash coal, 6 feet thick, with slate-partings in it. It dips gently S., being near the centre of the basin rising Eastward, and the road being near the E. end of this coal.

B. Vandermark's coal, near Hallenback's Mill, dips into a trough; it has 5 feet of coal with slate 10 inches thick in the middle—in all, 6 feet in thickness.

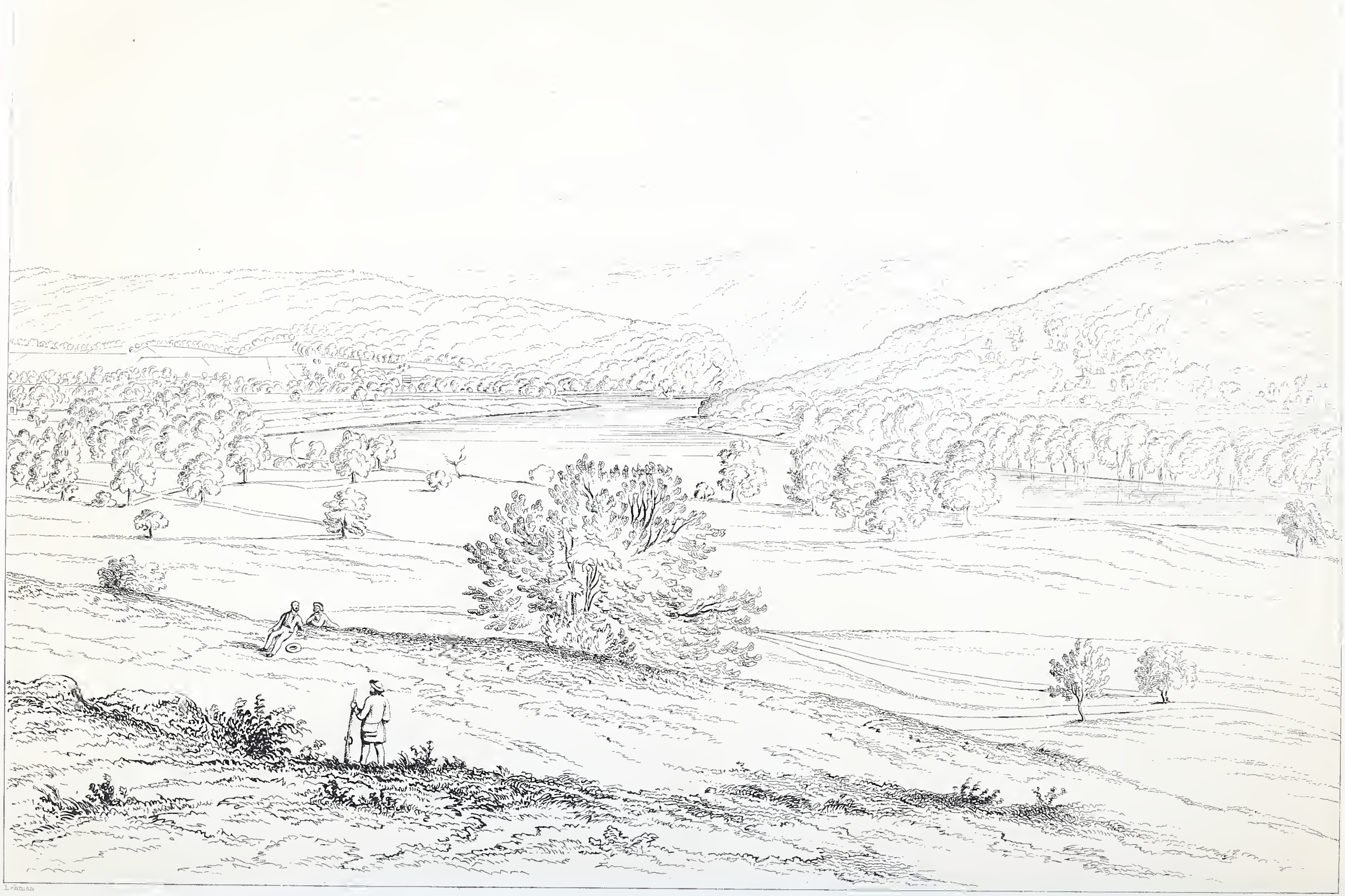
A little further W. is coal about 3 feet thick on Staymetz's Farm, now shut up; dips gently South.

Just N. of Hollenback's Mill on the road crossing over from Nanticoke Creek to the N. road, there is a double axis, very sharp, like that of Newport Centre: it is, I think, the same prolonged. It runs into the middle spur of the Mountain.

The synclinal of Vandermark's Hill runs from between the two ribs of the conglomeritic sandstone at the road, through the N. side of the valley of Nanticoke Creek. The anticlinal S. of it runs along the S. edge of the same valley.

We traced the synclinal and anticlinal axis of Vandermark's Hill eastward, and found that they died out by the time they approached the road from the Methodist Meeting-house to Newport Centre; they expire a little N. of the S. fork of the road.

The synclinal knob of sandstone a few hundred yards S.W. of Newport Centre on the same road is a more Northern synclinal, and the axis N. of it, or that first S. of Newport Centre, expires at the same road, and a little W. of it, and is the feeble axis of the road from Dodson's Schoolhouse northward. It does not go much W. of Newport Centre. All these gentle flexures of the road S.W. of Newton Centre imply a rapid declension of Vandermark's sharp saddle and basin.



Lehman

W. & A. K. Johnston, Edinburgh

NANTICOKE GAP, WYOMING VALLEY.

Iron Ores, Lee's Mines, Nanticoke.—Iron ore is said to exist beneath the 8-feet coal in three courses, within 20 feet of slate—

1st, Below the coal 20-inch balls of lean ore.
2d, 14 inches of stratified ore, quality not known.
3d, 6 inches of cubical stratified ore, rather lean.

The opening is now closed.

From Nanticoke Westward.—That portion of the coal-field which is W. of the parallel of Nanticoke presents much complexity of structure.

The Susquehanna River forsakes the coal-basin at Nanticoke to follow the deep trench in the Umbral red shale between the mountains of Vespertine sandstone and Seral conglomerate. Suddenly turning again to the left it crosses the W. end of the coal-field at Beech's Mines, leaving a small portion of the trough on its right bank, and escapes through the Southern Mountain into the Berwick Valley.

The Nanticoke Mountain presents to the river a bold and nearly perpendicular escarpment of outcropping Umbral red shale and sandstone. Its S. slope into the basin for some miles W. of Nanticoke is long and gentle, the result partly of a general gentle dip, and partly of numerous undulations. This structure prevails as far Westward as a notch in the summit of the mountain called Dean's Gap, W. of which the crest becomes a lofty ridge, nearly to the river, where it declines, and is composed of the conglomerate alone.

The Little Mountain, the S. boundary of the coal-field, is broken in its outline opposite to the Nanticoke Gap, by a series of gaps, and terminates at the Susquehanna in a bold knob.

The central part of the valley also becomes elevated and broken into ridges, the highest of which is known as the Hog-back. Numerous streams descending from the mountains enter the Coal-measures: one of these, Black Creek, rises in the valley between the Little and the Wyoming mountains, breaking through the former mountain nearly opposite to Schleppy's, and flowing Westward; it precipitates itself over a high and bold ledge of the Seral conglomerate, forming one of the most picturesque scenes in this valley, celebrated for its beauty.

One branch of the Nanticoke Creek, usually called the Forge Creek, rises a short distance W. of Dutter's, flows Eastward along the N. portion of the valley, and, uniting with another branch of the same stream coming from the S., empties into the Susquehanna not far from Lee's Coal-bed.

From Lee's Mine southward to the village of Nanticoke, several coal-beds have been opened, the dimensions and distances between which are given in the following description, which we have illustrated by a cut.

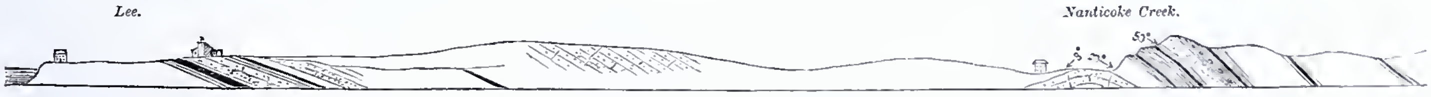


Fig. 292.—Section from Lee's, southward, at Nanticoke.—1 *inch* = 600 *feet.*

The uppermost coal-bed is called 5-feet thick, but it yields not more than 3 feet 6 inches of good coal; it dips 15° S.

An interval of 1000 feet horizontal (at 15° dip) succeeds coal, supposed to be a thin bed, exposed in a small run S. of Alexander's Old Store. Interval of 150 feet to a coal cropping out on the same run, passing a few yards S. of the Blacksmith's Shop: its thickness is unknown.

Interval, 50 feet. Coal, Thompson's bed, dip 25°, opened again near Forge Creek, where the dip is 12° S. 10° E.; thickness, 5 feet at the village. It contains coal 1 foot, slate 4 inches; coal 3 inches, slate 1 foot; coal 3 to 3½ feet, bottom slate containing carbonate of iron. At Forge Creek a tunnel is driven to it, where it reads thus: Coal, slaty, 1 foot; coal, 3½ feet, separated by 1 inch of slate; interval, 100 (?) feet; coal, bony vein, impure, slaty, 2 (?) feet, thin; interval; Mill's Vein, impure, slaty, 2 feet thin; interval, 100 feet. Coal, Mill's Vein, 7 to 8 feet; a good coal, burns freely, yields a white ash, has a conchoidal fracture. It runs S. of the Wilkesbarre and Nanticoke road. Interval, including a bed of carbonate of iron midway, 80 feet. Coal, Blacksmith Vein, said to be from 3 to 4 feet thick; crops out 115 feet N. of Mill's Vein, or just N. of the road. Interval, 80 feet; lower portion sandstone, quarried, dip 20° S. 10° E. Coal, Tunnel Vein, bent by an anticlinal, and dips 10° in opposite directions. The flexure is not traceable to the Eastern or Western bed, overlaid by slate. Interval, 35 feet. Coal, Forge Vein, 6 feet opened on the Creek; dip 15° S. 10° E. How far the lower great bed (Lee's) may lie below the Forge Bed is not certainly known. If the horizontal distance between their outcrops be called 300 yards, and the dip of Lee's Vein, 12°, be made an average (the rocks of the interval supposed, of course, to dip regularly), the one will underlie the other by 188 feet; if an average dip of 10° be preferred, 156 feet. Unknown flexures, however, may exist, and then they will approximate still more closely. By this supposition the Mill Bed falls naturally into the position occupied by the Baltimore Vein in the series of beds; that is, from 350 to 400 feet above the Seral conglomerate.

Along the Northern side of the valley few openings had been made up to the year 1840, at the date of our first explorations; nor have any important mines been established since. About 1½ miles from Lee's Mine, at the base of Nanticoke Mountain, Mr Holland had partially opened a large vein, 12 or 14 feet thick, which seemed identical with Lee's. Michael Gower had opened a vein, 7 feet in thickness, in the side of the River Mountain. Philip Haupt's Bed is also a 7-feet vein, and is probably the same as Gower's.

Michael Steinmetz had entered a coal-bed in the valley not far from the base of the River Mountain, and a short distance E. of the general section made at Schleppy's. It is 5½ feet thick. John Vendewert had also opened a vein of nearly the same thickness, and only a short distance from the former. The two openings are probably on the same vein.

A general section made across the valley at Schleppy's, 5 miles W. of Nanticoke, embraces several good beds of coal.

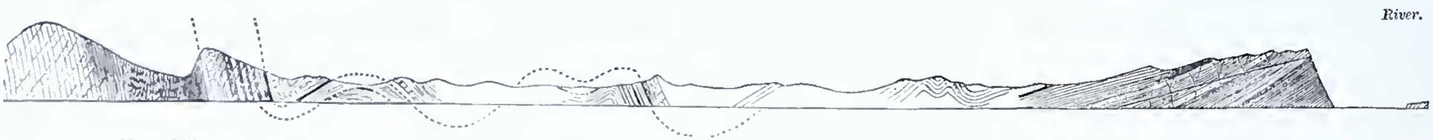


FIG. 293.—Section across the Wyoming Coal-basin, 5 miles W. of Nanticoke, or through Schleppy's.—1 *inch* = 2000 *feet*.

The summit of the Nanticoke Mountain is occupied by the alternations of the Seral conglomerate and the high beds of Umbral sandstone and shale: only its Southern brow exhibits the coarse main mass of conglomerate. Upon the slope the Coal-measures appear with gentle dips: Miller's Bed dips 20° S., opened at a considerable distance from the summit, and is said to be 7 feet thick; its position in the series could not be ascertained. From Miller's coal to the beds of the Hog-back the exposures are few; but the dips observed show that there are several flexures.

The Hog-back.—Forge Creek breaks through the ridge, and finely exposes the strata in the gap. The following vertical section exhibits the number and thickness of the beds: The upper coal, called the Thornton Vein, dips 35° N., and is said to be 9 feet thick. The next vein to the S., 80 or 90 feet below the Thornton, is a coal which has not been sufficiently developed; only 5 feet of it were seen. The next vein, called the Perpendicular Vein, measures from 12 to 16 feet in thickness; it is exposed on both sides of the creek. On the W. side this coal measures 16 feet, and is apparently less crushed than on the E. side. Under this bed occurs a hard coarse carbonaceous sandstone, 45 feet thick; then a coal-bed, from 6 to 12 inches; then slate, 9 feet; under this a band of impure iron-ore, nearly 2 feet thick; then dark coarse carbonaceous sandstone, 22 feet. Below this the strata to the next coal-bed are not well seen. The next coal-bed was insufficiently opened, but exhibited 5 feet of coal.

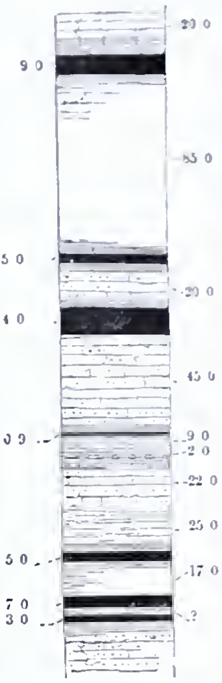


Fig. 294.—Hog-Back, 5 miles W. of Nanticoke.

Server's Vein lies 17 feet below the last, and is from 6 to 8 feet thick. Its coal is somewhat crushed, being near the flexure. A short distance below it lies another bed, said to be 3 feet thick. The entire thickness of coal-measures embraced in this section is about 36 feet. The Perpendicular Vein, so called, may possibly be the same bed as Server's and Holland's.

Proceeding Southward with the section, Server's coal-bed by a roll turns to a S. dip of 20°, rising, however, again at a short distance with a gentle N. dip. Beyond this a great extent of surface Southward exhibits no exposures, but doubtless contains a synclinal trough simple or complex, in the N. portion of which the Hog-back beds may descend and rise again, dipping Northward. Here is seen a bold bluff formed by the outcrop of a coarse pebbly sandstone. Beneath it appears a coal-bed, which may be the great bed. Some distance farther S., and almost on the axis of the anticlinal that separates this synclinal from the next, or that which runs along the foot of the Little Mountain there, is seen another coal-bed, and farther on, and among S. dips, a thin bed of iron ore. A bold ledge then succeeds facing the N., and corresponding to that last described, containing the outcrop of a coarse pebbly sandstone, with that of the great coal-bed at its foot. Still farther up, this rock forms a high hill capped with sandstone, behind the summit of which is an upper bed of coal, at the old turnpike road, lying cramped in the very axis of the synclinal trough. From this point Southward up the long slope of the Little Mountain, the rocks crop out with a very steep N. dip. First is seen the final outcrop of the great bed 12 or 14 feet thick, with a slate near the middle, and beneath it a massive sandstone. No more coal-beds are visible between this line and the conglomeritic strata which form the upper slope and summit of the mountain, on the S. side of which vertical precipices overhang the narrow valley of Umbral red shale.

From this general section, it is apparent that the strata of the basin are much disturbed or undulated. The coal-opening made by Holland for the Wyoming Coal Company, near the base of the mountain, and the outcrop of the great bed (Knoop and Stiver's), dip S. into the mountain.

In consequence of the upturning in the strata, this great bed has been spread over a considerable surface. Koker's bed is opened a short distance E. of our principal section on the S. dip of its synclinal roll; the bed itself exhibits some disturbance.

Krupp's coal-drift is perhaps half a mile E. of Koker's, and in the same position, near the foot of the Little Mountain. Its dip is to the S.W., about 14° on the N. side of the synclinal trough.

The Wyoming Coal Company opened this large bed in two places along the base of the Little Mountain. One of these is not far to the Eastward of Cooper's, though it lies a little further to the S., or nearer the mountain. Where the drift enters the bed it is horizontal, and continues so for 200 feet, when it rises with a N. dip, which increases to 55° towards its outcrop on the flank of the ridge.

The thickness of this coal-bed, roughly measured, is 18 or 19 feet : its character, as well as it could be ascertained, is as follows :—

Coal, 8 or 9 feet, good quality, slate 2 feet ; *coal,* 2 feet 9 inches, good ; *coal* 9 inches, slaty ; *coal,* 1 foot 10 inches, good ; *slate and dirty coal,* 1 foot 10 inches ; *coal,* 2 feet 9 inches, under slate ; coal and Stigmaria. Near the entrance to the drift the upper portion of the vein was distinctly seen, where it presents 8 or 9 feet of excellent coal. Farther to the Eastward, in a corresponding position, Holland's second opening occurs. It has been entered by a tunnel. Rocks are observed in a ledge 100 feet or so in front or N. of the tunnel, dipping 35° N. In the tunnel the dark-grey coarse sandstone at its entrance rises at first into N. dips, but gradually falls, and rolls over to the S. The coal-bed, where entered by the tunnel, dips gently to the S. If the tunnel were driven farther in, the vein would doubtless be again intersected where it rises with a N. dip to its outcrop on the mountain's side.

About 200 yards E. of the latter opening, in a ravine, several coal-beds were observed evidently underlying the large bed.

The first bed in the section on a line with the tunneled bed just described was nearly horizontal, inclining perhaps a little to the S., then gradually rising till it outcrops on the bench that skirts the mountain. The strata continue rising with a N. dip of 50°, constituting a fine exposure of rather flaggy sandstone, underneath which is a coal-bed, of a thickness unknown. Under the coal vein occur 6 feet of compact slate, succeeded by a heavy mass of sandstone, from 35 to 40 feet in thickness, with an average dip of 20°. It is a coarse grey rock, full of small pebbles. A few feet of slate succeeds, then a band of iron ore 10 inches in thickness, apparently of good quality. A thin seam of coal underlies the ore ; slate next appears, embracing several thin bands of ore, followed by a coal-bed 7½ feet thick, and reading thus : Coal, impure, from 6 to 12 inches ; slate, 14 feet ; coal, 2 feet ; slate, 6 or 7 inches ; coal, 4 feet, generally good, but slaty in the middle. The bed dips about 30°. N. It is underlaid by sandstone, then a little slate, when suddenly at a waterfall the strata dip steeply S., nearly vertically. Underlying the main mass of sandstone which forms the falls, there occurs a vein of coal, rather crushed, about 7½ feet thick. Evidence of another seam, perhaps thin, is observed 20 feet N. of it. From this point up the ravine nothing farther could be seen, and the rest of the section is completed from the few exposures in the side of the mountain.

Tracing the large vein Eastward, it appears again at Stiver's Bed, at the base of the Little Mountain, nearly opposite Nanticoke. Its dip is S. about 15° into the mountain, corresponding in position to the opening above described. Further up the mountain it crops out, with a dip of 30° N., from which, to the summit of the mountain, the dips gradually increase, becoming 70° in the Seral conglomerate. At the old opening, a fourth of a mile S. of Mr Lyon's house, it reads thus (top slate, from 20 to 25 feet) :—

Coal, crushed, 4 *inches ;* checkered, 11 *inches ;* slate, one-eighth of an inch.
Coal, 11 *inches ;* slate, one-eighth of an inch ; *coal*, 11 inches ; slate, one-eighth of an inch.
Coal dirt, with thin seams, 18 *inches ;* slate, 1 inch.
Coal, 8 *inches ;* slate, 3½ inches.
Coal, 22 *inches*, dirty ; *pure*, 12 *inches ;* slate, 4 inches.
Coal, 33 *inches ;* slate, 1 inch.
Coal, 10 *inches ;* slate, 3 inches.
Coal, 32 *inches ;* slate, 2 to 3 inches.
Coal, 26 *inches ;* bottom slate ?—18 feet.

West of the section made at Schleppy's, the only veins mined to any extent were those opened by Mr Henry Colt of Wilkesbarre, for the Philadelphia Company, about 3 miles from Schleppy's, or one mile W. of Mr Dulter's. The valley gradually contracts in breadth, and the Coal-measures lessen in thickness, and the conglomerate occasionally makes its appearance in the floor of the valley. One of Mr Colt's openings is at the foot of the Nanticoke or River Mountain, and has a thickness of nearly 16 feet ; it is undoubtedly identical with Lee's. The following is the character of the vein, so far as it has been developed (the drift has only been driven in for a short distance) :—*Coal*, not mined, 5 *feet ; Coal*, 4 feet 6 inches ; slate, 6 inches ; *Coal*, 4 feet 6 inches.

Over the vein occurs a greyish micaceous sandstone for 2 feet, surmounted by a great mass of a very coarse grey sandstone.

A large bed of coal, 13 feet thick, was opened by Mr Colt at the S. base of the ridge called the Hog-back. Black Creek flows between this ridge and the Little Mountain. The coal-seam lies under a heavy mass of coarse sandstone, similar in appearance to the rock overlying the large 16-feet bed, with which there is every reason to believe it identical.

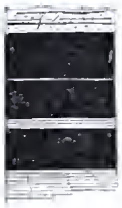


FIG. 295.—Colt's Coal.

Above the 13-feet vein in the Hog-back (distance not known), occurs another, about 6 feet thick.

The following section, made half a mile W. of the preceding opening, on a line running S. from Black Creek, will show the contorted character of the strata of the Little Mountain.

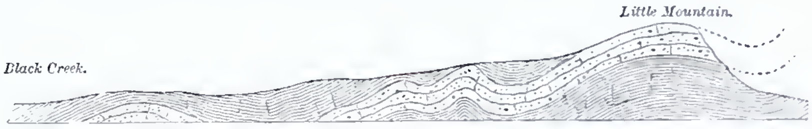


FIG. 296.—Contortions in Little Mountain, E. of Susquehanna River.

West of the mines of the Philadelphia Company, as far as the river, few beds have been opened. The large vein has probably been struck in one locality, 200 yards from the river : here it is about 8 feet thick.

In the valley at Black Creek Falls the conglomerate appears, and the section (fig. 296) showing the structure will at the same time exhibit the shallowness of the Coal-measures.

About a mile eastward of the section at Schleppy's house, Mr Kreemer has exposed a vein of coal 3 feet thick, and higher up the same stream has made a boring into a large vein of coal, from 8 to 9 feet in thickness. From this point a section to the summit of the River Mountain strikes the top of the mountain at a large exposure of massive strata, known as the Big Rocks, E. of the notch called Dean's Gap.

Houpt's bed, to the W. of the last section, dips 15° or 20° S., and corresponds in position to the bed reached in Kreemer's boring. A gentle undulation occurs to the N. of it, which passes also N. of Beattie's, at the gap. The bed may be traced W., and will probably be found under a ledge of rock S. of Mr Beattie's, where the Seral conglomerate is near enough to prove that the bed is low in the series of the Coal-measures.

Coal-Basin W. of the Susquehanna.—A few miles W. of the Susquehanna the termination of the Little Mountain, or, as it is here called, the *Stony Ridge*, unites with the Nanticoke Mountain in a bold knob. The Coal-measures remaining on the Seral conglomerate are thin, and cannot embrace more than two, or at the utmost three, distinct beds; and these, owing to the highly-disturbed condition of the strata, must be in a considerable degree crushed and faulty, as at Nathan Beach's Mines, at the base of the mountain, rising from the river. Along the River Road the Umbral red shales are well exposed in a shallow double synclinal flexure.

The central elevation here is called the Southern Hog-back. As we ascend the face of the stony ledge, the dip of the conglomerate rocks increases, being at Beach's upper drift 35° N. The coal-bed opened here is so crushed that its true thickness could not be properly estimated.

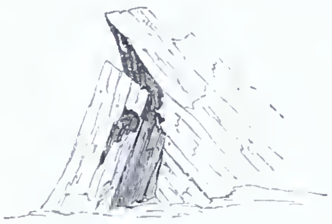


Fig. 297 (*b*).

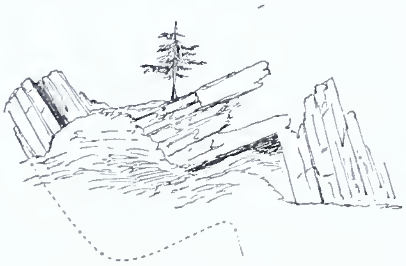


Fig. 297 (*a*).

About 100 feet from Beach's upper opening, to the N., there occurs a sharp roll (diagram *a*), in tracing which up to the top of the mountain, the dips, especially the N., are seen to increase, becoming 70°, and the whole flexure is sharply broken, as in the sketch *b*; the rocks are coarse-grained pebbly sandstones, and perhaps underlie the coal. The flexure is traceable some distance W. As we proceed toward the termination of the coal-field these flexures appear more frequently, and the strata everywhere exhibit evidence of great disturbance.

The Seral conglomerate is sometimes observed far down the flank of Stony Ridge. The Vespertine shales occasionally occupy the entire summit of the Nanticoke Mountain. The strata of Stony Ridge, or the S. rim of the terminal basin, are evidently more disturbed and contorted than those of the Nanticoke Mountain, forming its N. dip; and this is true of the Wyoming Basin as far E. as Wilkesbarre.

The following section, made about a mile W. of the river, shows the numerous undulations in which the basin ends. Here Stony Ridge or Little Mountain is entirely occupied by the Seral conglomerate and overlying Coal-measures; the former appearing in a most unusual place—that is, nearly in the bed of the valley. Whenever, on the N. side, the Umbral shales spread over the entire summit of the Nanticoke Mountain, the Coal-measures extend in a succession of waves over the intervening space. Coal has been opened by Mr Jamieson on the line of section, but cannot occur much further W.

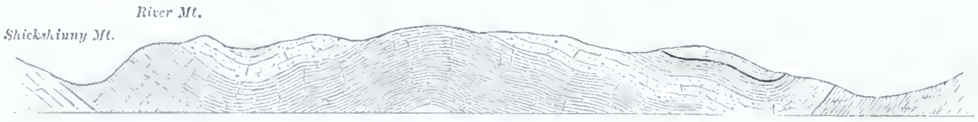


Fig. 298.—Section across the Coal-basin at its Western End.

The flexures, short and sharp, which have been so often described, also occur beyond the limits of the coal. One such is seen at the falls of the Shickshinny Creek, in the rocks of the Vespertine sandstone.

Iron Ores.—Among the Coal-measures of the Wyoming Basin, beds of iron ore of proper size for mining have not been discovered; occasionally thin beds are found, but not of sufficient thickness to be valuable. The only iron ore as yet mined to any extent occurs in the rocks underlying the Seral conglomerate. The mines have been opened on the S. side of the Lackawanna Valley, about 6 miles above Pittston. The ore is found near a little stream called the Meadow Run, which empties into Roaring Brook. Its position is in the greenish buff sandstones marking the transition from the Vespertine shales to the Seral conglomerate. These strata must be here of considerable thickness; the Vespertine red shale is not apparent near the mines.

The ore, interstratified with the sand-rocks, dips more than 10° N.W. The thickness of the vein varies; in one drift, near the entrance, it was $1\frac{1}{2}$ feet thick, increasing to 2; in higher drifts its thickness was 3 feet, increasing even to 4. Above the ore is fire-clay, in which, in some places, are found imbedded large balls of ore, through a thickness of perhaps 1 foot.

An impure limestone is found not far from the ore, in the same series of rocks.

(For a more precise description of this iron ore, see account of the Iron Ores of the vicinity of Scranton, p. 357 of this volume.)

CHAPTER VI.

WYOMING, KINGSTON, AND PLYMOUTH DISTRICT.

The last district of the coal-field which remains to be described, is that embraced between the Shawnee Mountain and the river Susquehanna, from its entrance into the basin at the mouth of the Lackawanna, to its exit at the Nanticoke Notch. More than one-half of the area of the Coal-measures included within this district is occupied by a deep, and hitherto an almost unpenetrated, superficial stratum of diluvial drift, the depth of which has been probed only in one or two spots. In the present unexplored condition of this large and valuable portion of the basin, it would be idle to attempt any conjectures respecting its underground structure, or the positions of the coal strata within it, beyond perhaps the inference that several of the more persistent and bolder anticlinal undulations of the Pittston district to the S. of it must penetrate it, or even nearly cross it, before they altogether expire. From a study of the structure of the Pittston district, we are perhaps warranted in assuming, moreover, that the coal strata beneath these flats are, on the whole, less undulated or disturbed than in the district S. of the river, between the Lackawanna and Wilkesbarre.

The anticlinals which do exist are probably prolongations of those of the Pittston district, and not of the set emanating from the N. side of the valley.

At what depth the Coal-measures are to be reached below the surface of these Wyoming and Kingston flats remains to be ascertained, but borings now in progress and in contemplation will soon settle this question. I deem it probable that the drift stratum has in many places, if not generally, a thickness of at least 100 feet.

I pass now to the consideration of the structure of that part of the district which lies between the diluvial flats and the conglomerate border of the Coal-measures on the Shawnee Mountain.

Monoclinal South-dipping Belt of Strata between the Pittston Gap and Hertzoff's Hollow.—This is a narrow strip of Coal-measures in but few places exceeding half a mile in breadth, extending from the edge of the flats at the foot of the mountain to the final outcrop of the Coal-measures which rise to various elevations on the mountain, dependent on the local erosion of its surface.

This mountain-limit of the coal recedes gradually from the flats as we advance W., being not more than a fourth of a mile N. of them opposite Pittston, and about three-fourths of a mile as we approach Kingston. The actual line of outcrop traced in detail will be found to be an undulating or scolloped line, sweeping highest on the mountain in the space midway between each cross ravine, and descending both ways to a point into each notch or hollow.

We have defined this belt as one of monoclinal structure, and such it essentially is, no notable undulations occurring within it; nevertheless there are probably—more especially towards its W. limit—some very gentle undulations of the dip, scarcely amounting to an actual reversal in direction, but merely to a flattening of the prevailing S. pitch. These will manifest themselves hereafter, in the progress of mining.

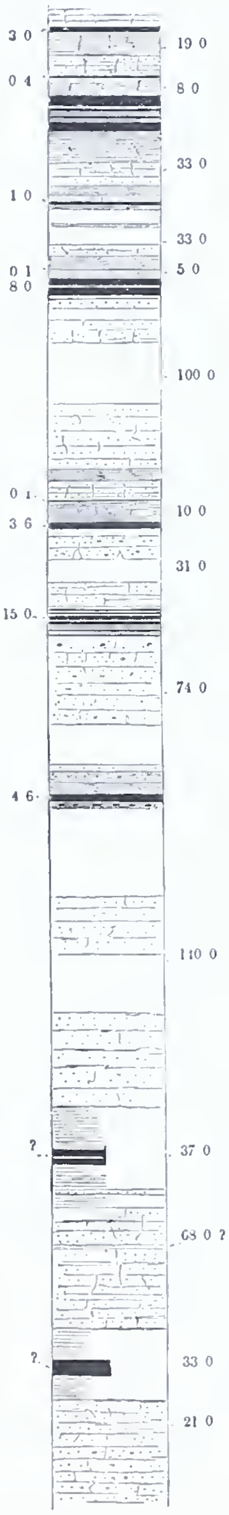


Fig. 299.—Column of Coal-measures visible in Shoemaker's Ravine, N. of Kingston.

OF THE COAL-BEDS HITHERTO DISCOVERED IN THIS BELT.

The accompanying vertical section, compiled chiefly from observation in the ravine N. of Kingston, and along the mountain to Hertzoff's Hollow, represents what is at present known respecting the coal-seams of this belt. Those represented hypothetically toward the base of the column were opened many years ago on Toby Creek by Mr Raub. They are represented under their most favourable thicknesses in the cut, (Fig. 299.)

Excepting these lower seams, which occupy a position low down in the series, our section represents only three, or at most four, seams of valuable thickness, and the range of these is such, that they have not yet been mined very extensively. They were observed many years ago, when freshly opened, in Shoemaker's Ravine.

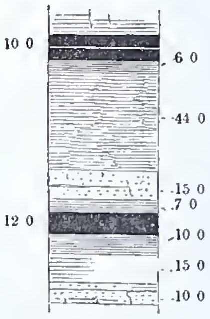


Fig. 300.

The two upper workable seams, dipping about 35° S., are subdivided as follows:—

Coal, 6 feet 6 inches; black slate, 12 inches.
Coal, 6 inches.
Coal and carbonaceous shale, 2 feet; black slate, 2 feet.
Coal, 1 foot; shale, 2 feet.
Coal, 5 to 6 feet.

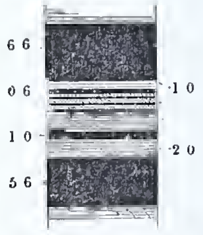


Fig. 301.—Coals in Shoemaker's Ravine.

On the other side of a narrow synclinal trough there is a change in the intervening measures, as the section will illustrate.

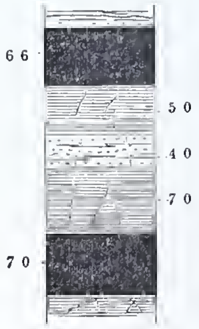


Fig. 302.

The poverty of workable coal-seams in the lower part of the formation is quite striking; the more so, when we contrast it with the abundant size of the great coal-stratum in the same horizon, traceable, as we shall see, from Nanticoke Gap almost to Hertzoff's Hollow, and when we advert to the magnitude of the lower beds on the opposite side of the basin S. of Wilkesbarre. It is only to be explained by supposing, what so many facts in the comparative geology of the lower Coal-measures suggests, that the main great bed, in its distribution N., either becomes rapidly exhausted by actual thinning, or subdivides, and loses its identity, by the parting asunder of the several tiers or benches which constitute it a compound mass, where it is thickest. If our identification be correct, the mass of coal and slate represented in the section as 15 feet thick, and analysed in the accompanying woodcut, is a confirmation of this view.

In like manner the large Plymouth Bed, traced E. to Toby Creek, seems to have dwindled down to no more than 9 or 10 feet.

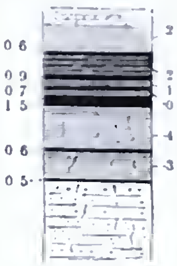


Fig. 303.

Iron Ores.—In Hertzoff's Hollow, or the gap N. of Kingston, and in the Vespertine series, between 500 and 600 feet below the Seral conglomerate, two bands of iron ore have recently been developed. They are included within a mass of olive ferruginous shale, which occupies the interval between two heavy ledges of conglomeritic sandstone. The ore is black, ponderous, and very silicious ; indeed, the mass might be termed a fine conglomerate, the pebbles of which are cemented together by the ferruginous paste that constitutes the ore. As thus far proved, the upper bed measures from 2 to 3 feet, and the lower upwards of 4. They are separated by 5 feet of hard rock. From the irregularity of shale floor and roof, the thickness of the bands, it is thought, will prove variable.

Limited quantities of the ore have been transported to Danville, and smelted with profit.

The Plymouth Belt, or that extending from Kingston to Nanticoke Notch.—In the interesting division of the coal-field now before us, the maximum breadth of which at Ross Hill a little exceeds one mile and a half, we have a district remarkable for the gentleness of its dips, and consequently for the long breasts of coals which it includes above the water-levels of its intersecting valleys. It embraces some seven or more discernible anticlinal undulations, two of which are long, and rather conspicuous ones ; but the influence of even these is trivial in interrupting the very general prevailing Southward inclination of the strata. This gentle dip of the Coal-measures towards the river permits the working of long breasts of coal towards the mountain, and facilitates greatly the transport of the coal over gently-descending grades, and allows it an outlet by tunnels to the adjacent navigation : it is a feature in the structure of this district which confers upon it almost pre-eminent mining advantages, reminding us, on a small scale, of the facilities enjoyed by many portions of the great basin of South Wales, the largest coal-field of Great Britain.

I proceed to define the situation of the flexures hitherto detected in this district.

Undulation A *of Belt* 20, *or Plymouth District.*—This is a local undulation in the strata, visible near the intersection of the road leading N.W. from Kingston, over the mountain, and Schupp's Creek. It is marked by decided N. dips, visible on the road as we commence the ascent of the mountain N. of the stream, the inclination amounting to perhaps 20°. This is soon followed, however, by the prevailing S. dip, as we enter the strata which include the two lowest coals, or Hoyt and Jaquish's ; it is therefore obvious that the flexure is one of trivial influence. How far it extends E. and W. of the road cannot be ascertained till mining develops it farther. So extensive is the covering of drift upon the hills of this side of the valley, that the tracing of these lesser axes by merely surface-marks is an almost impracticable task.

Anticlinal B *of Belt* 20, *or that of Gaylord's Mine on Pine Swamp Run.*—The next flexure which arrests our attention in this part of the coal-field is a flat undulation, visible just at the mouth of the old Cooper Mine (now Gaylord's). This lies a short distance within the mine, and, as it is subsiding Eastward, has the effect of curving the gangway, which is now running N.E. out of its proper course, somewhat more Eastward, and then back again. Its effect, however, is trivial.

Anticlinal C *of Belt* 20.—About 500 feet S. or S.E. of the mouth of Gaylord's Mine, another rather more considerable flexure crosses the same valley, between Gaylord's Mine and Levy and Patton's. The effect of this is to lift out the upper or Cooper coal of the neighbourhood from below the water-level of the stream, and to produce the N. dips a little in front of Gaylord's Mine. Some vestiges of this anticlinal are discernible on the by-road leading from the mines to the road running N.W. from Kingston. We detect this anticlinal to the Westward of the stream in Levy and Patton's Mine, not far from their old gin-slope, where its effect is to elevate the Bennet or Patton Coal, that next beneath the Cooper bed, almost to the surface.

Flexure D, *or that of the Mouth of Levy and Patton's Tunnel.*—A trivial flexure occurs just within the mouth of Levy and Patton's tunnel, producing a perceptible dip Northward in the strata ; of the extent and the effects of this we know very little.

Anticlinal E, *or that of Wadham's Mine.*—We have next to consider a flexure of more length and apparent importance than the four above enumerated. It is one which seems to come off, like the others, obliquely from a high point on the flank of the mountain, and is traceable in a straight course for some two miles as far Eastward as the cross road leading from Schupp's Creek northward towards the mines. This axis, nowhere accompanied by steep dips, is barely discernible on the cross road mentioned, and seems as if this were its commencement or termination. It is seen in its greatest distinctness on the little stream which flows by Wadham's Mine, N. of Plymouth, and again on Smith's Creek farther Westward. At Wadham's, the whole breadth occupied by the flexure is very small, its N. dips not occupying a space of more than 100 feet, and 20° or 30° being the extent of the N. dip ; from which it may be seen that the effect of this upward flexure of the rocks on the distribution of the coal is trivial. It nevertheless has the effect of separating the first outcrop of the Cooper or Orchard Bed from the lower outcrop of the same seam, worked at present by Wadham in the basin N. of it on its second Northward rise.

On Smith's Creek this axis is somewhat more conspicuous. It there embraces a double wave, a Southern and wide undulation, apparently the principal one, and a Northern and sharply compressed flexure, showing both dips with a steepness of 80° over a very narrow space.

The effect of this anticlinal on Smith's Run is to lift out what is there called the Reynold's Coal, or the seam next above the great lowest bed, or that of Smith's Mine, and to leave it no space to basin again farther N. This Reynold Coal, being apparently the equivalent of the Bennett or Patton Coal, or the seam next under Wadham's—the equivalent of the Cooper or Orchard bed—it is plain that the axis in thus lifting it out has continued to rise, in its Westward course, from the neighbourhood of Wadham's Mine. How far it ranges to the Westward of Smith's Run has not been ascertained.

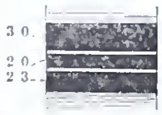


FIG. 304.—Reynold's Small Bed on Smith's Creek.

Anticlinal F, *or that S. of the Basin of French's Tunnel.*—Succeeding the axis of Wadham's Mine, and situated about 1000 or 1100 feet S.E. of it, ranges another much longer parallel anticlinal wave, traceable from N.E. of the village of Plymouth to the Mountain-notch of Nanticoke. This is an important flexure in all the mining ground W. of Smith's Creek ; our first or most

Eastern indications of it are on the W. side of Gaylord's Railroad, half a mile N. of the turnpike, where the arch is distinctly discernible in a small railroad cutting, but where the N. dips, however, are of very limited breadth. From this point to Smith's Run it is only obscurely visible; but a little W. of that ravine it becomes conspicuous in the topography, and begins to manifest itself as a prominent though narrow flexure. It first enters the Southern protuberance on the S.E. slope of the main hill next N. of the turnpike road, and then ranges along the crest of this hill, displaying a beautiful and symmetrical arch at the ravine running S. from French's Tunnel, arching the rocks in fact the whole distance to Lance's upper mines, and to the deep notch in the end of the mountain N.W. of Harvey's. Increasing in steepness from Smith's Run westward, it exhibits a N. dip of 60° at French's Run, and an almost perpendicular one N. of the Grand Tunnel; while beyond the latter point, as we enter the narrow defile in the end of the mountain, it appears to pass into an actual dislocation, obliterating altogether its Northern dips, and causing the South-dipping strata of the N. side of the basin N. of it, and a large patch of the lowest or Big Coal, to abut violently where the axis should be, against the rocks composing the S. leg of the broken arch. From the hill W. of Smith's Run to the head of the gorge containing the dislocation, the basin N. of this flexure is a very regular and symmetrical one, characterised, however, by much gentler S. dips than N. ones.

It is on the N. side of this little basin that French's short tunnel perforates the sandstones overlying the lower or great coal-beds, and it is likewise on the same S. dip or upper outcrop of it that Lance's upper mines are seated on the Grand Tunnel property. And it is likewise in the same general strike, and on the same side of the same synclinal, but replaced here by a prodigious fault, that the large insulated patch of the Big Coal occurs on Harvey's property, near to the Western end of the mountain, in the knob overlooking the ravine. Throughout the entire course of this anticlinal, as it gradually rises Westward until it approaches its points of dislocation, the great or lowest Coal-bed nowhere rises out to the surface, but is oversaddled by the next higher rocks. It is not until we reach a point about due N. of Harvey's Tunnel that the denudation and the Westward rise of the anticlinal combine to remove these overlying strata, and to expose to view the large coal upon the anticlinal axis. Elsewhere, in order to enter that portion of this coal which basins to the N. of the anticlinal line, it will be necessary to tunnel into it from points lower down the hill, selected at such elevations on the S. side of the anticlinal flexure, as by calculation will just carry the tunnels to the synclinal part or deepest centre of the trough.

Anticlinal G, *or that of the S. Edge of Ross's Hill.*—A feeble flexure is traceable along the Southern edge of Ross's Hill south of the main road, and adjacent to it. It is the cause of the N. dips seen on that road E. of Schupp's Creek; and it may be detected in a corresponding Northern dip farther Eastward in the bluff of the hill S. of the road.

It does not seem to cross Schupp's Creek, or at least no considerable flexure has hitherto been detected in the Gould Coal-bed in Shunk's mine W. of that stream.

COAL-MEASURES AND WORKABLE COAL-SEAMS OF THE PLYMOUTH DISTRICT.

In the district before us there would appear to be four workable beds of ample dimensions for mining, and one, and sometimes two of these, are of unusual size.

1*st, The Plymouth Great Bed.*—The first or lowermost in the series is the Great Nanticoke

Bed. This at Harvey's, and at Lance's Grand Tunnel Mine, the two most Western of the district, has a total thickness of about 22 feet, yielding in the first-named mine about 12 feet of coal, and in the other a total of 17 or 18 feet. At Smith's Mine, nearer Plymouth, the whole thickness of the compound seam is a little more than 17 feet; while, by the time it reaches Jaquish's, on the road N.W. from Kingston, though still further reduced, it retains the dimensions of an ample bed.

(An inspection of the several sections of this Coal-bed, as it exists at the chief localities, will best show its composition and the changes which it undergoes.)

At Harvey's Mine, where the great bed crops out from under the continuation of Thomas's sandstone bluff, the bed dips 15° S., and is from 18 to 20 feet thick; over it is slate 3 feet thick, on which rests a dark-grey, fine-grained, micaceous sandstone, 18 inches thick; and over this, coarse sandstone and fine conglomerate. Coal was taken from this mine more than twenty-five years ago. The present mouth of the mine is at water-level at the level of the road. The gangway runs N.E., and there are thirty-six breasts in the mine from the lower gangway to the outcrop; these are each 25 feet wide, and the average width of the pillars is 14 feet. The whole length of the breast of coal to the outcrop must be half a mile; the length of the gangway was (in 1854) 1450 feet. The subdivisions of the seam are,—

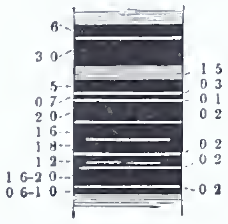


Fig. 305.—Great Plymouth Bed, Harvey's Mine.

Coal, 1 foot 6 inches; Slate, thin; Coal, 3 feet; Slate, 17 inches; Coal, 1 foot 5 inches, pyritous; Slate, 3 inches; Coal, 7 inches; Slate, 1 inch; Coal, 2 feet, poor; Slate, 2 inches; Coal, 1 foot 6 inches; Slate, thin; Coal, 1 foot 6 inches; Slate, 2 inches; Coal, 1 foot 2 inches; Slate, 2 inches; Coal, 1 foot 9 inches; Slate, 2 inches; Coal, 9 inches.

Big Coal in Lance's Grand Tunnel Mine.—The upper bench has from 12 to 13 feet of coal in all, but the lower and upper parts are the finest, and the average amount of good coal is 10 feet.

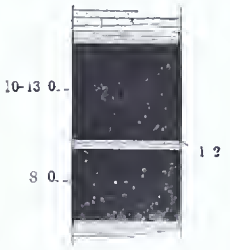


Fig. 306.—Plymouth Big Bed, Lance's Grand Tunnel.

Slate, from 1 to 2 feet; coal, having a dull lustre, yielding a red ash, and breaking with a conchoidal fracture, 8 feet.

2*d*, *Bennett's or Patton's Coal-bed.*—The second coal in the series, known near Plymouth as Bennett's or Patton's, is usually situated about 55 or 60 feet above the lower great seam, the space between them probably enlarging as we go Eastward. The usual thickness of this bed N. of Plymouth is about 10 feet; but the equivalent seam farther Westward in the district, in the neighbourhood of the Grand Tunnel, has a thickness of 5 feet. In the intermediate ground on Smith's Creek, this seam, there called Reynold's, possesses intermediate dimensions, having a thickness of about 7½ feet.

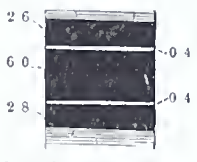


Fig. 307.—Levy and Patton's.

Bennett and Patton's Mine worked from the Tunnel.—The tunnel is about 300 yards long; at its mouth the Cooper (Orchard) Coal lies 12 feet below the surface. The tunnel passes this bed, then rock for 200 yards, and then reaches the Bennett Coal. The dip is very gentle. The benches in Bennett's Coal are,—

Slate and Coal-slate, 2½ feet; Stony Coal, 3 feet; Pretty good Coal, from 4 to 4½ feet; Slate, 2 inches; the best Coal, 3 feet.

3*d*, *The Cooper or Orchard Bed.*—Overlying the second coal-bed, by an interval varying according to the neighbourhood from 40 to 60 feet, is a third bed, generally called Cooper's, believed to be identical with the so-called Orchard Seam, N. of the village of Plymouth. This coal-seam is about 6 feet in size in the neighbourhood of the Grand Tunnel; at Wadham's it is

7½ feet thick, and in Orchard's Mine 8 feet; but at the Old Cooper Mine, 1 mile further to the N.E., it measures in all 10 feet, though some distance back in the mine it is a foot thicker, and there yields at least 9 feet of good coal. (See its subdivisions in the cut, fig. 309.)

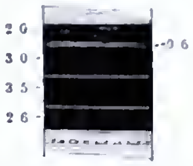


FIG. 308.—Gaylord's Coal, Cooper Bed.

The Cooper Coal, Pine Swamp Run.—This mine is a regular pillar and breast-work mine, its roof being supported entirely by pillars of coal. The "board and head" are quite well marked in the mine. The coal is 10 feet thick. The top is slate, laminated.

Coal, 1 foot 6 inches; Slate, 6 inches; Coal, 3 feet; Fine Blacksmith's Coal, from 3 to 3½ feet; Short Coal, from 2 to 2½ feet.

Blue clay-slate, with large flat balls of iron ore.

The underlying slate and shale are quite thick. The Cooper coal burns freely, and is yet an excellent enduring fuel.

An anticlinal axis, wide and flat, passes just through the mouth of the Old Cooper Mine, and swings the roadway a little to the Eastward and back again Westward.

There is an anticlinal about 1000 feet S. of the crossing of the two railroads.

4th, The Gould Coal-bed.—Next above the Orchard Seam lies the Gould Bed, though many persons have supposed the two beds to be identical. This seam appears to be restricted to Ross's Hill and the knob next W. of it, and not to cross the valley of Cooper's Creek or the Pine Swamp Run. It is at present mined from the water-edge at the river, just W. of Schupp's Creek, in the Rudmund-dale Colliery. This bed has an average thickness of 6 feet, yielding that much of good coal, excepting a 2-inch layer of slate in the middle. The quality of the coal is excellent.

Gould and Shunk's Mine.—At the mouth of Schupp's Creek, or Rudmund-dale, this coal has been wrought languidly for thirty years. The coal dips gently S.E.; it just comes down to the edge of the ravine at the mouth of the mine, and is 43 feet below the bed of the Creek at the crossing of the main road. This coal has an average thickness of 6 feet, and yields all coal except 2 inches of slate in the middle. Its divisions are as follows,—

Slate Roof; Rough Bird's-eye Coal, 3 feet; Good clean Coal, 3 feet; Excellent Coal, 1 foot; Slate Bottom.

The only gangway is at the water-level, and runs N. 60° E. for about 35 rods (600 feet). The coal is sent to market chiefly in lump form, and is used in iron furnaces. The outcrop of this coal crosses the road 200 yards E. of Culver's house in Plymouth. The outcrop of the 6-feet bed is also seen at Schupp's Creek. The upper limit of it on the hill is about 1300 feet N. of the road from the mine.

Mr Dodson is working the outcrop of the "Big Coal" at the foot of the mountain, and the middle coal has been opened on its outcrop 600 feet S. of it.

On Nesbit's property, E. of Gaylord's Railroad, the second coal, 7 feet thick, contains checked or bird's-eye coal of good quality.

The *boring* on Mr Gaylord's land in Plymouth begins in the floor of the Orchard or 8-feet Upper Coal of this vicinity. It is supposed to be the Cooper Coal, though distant a mile from it. The following is a section of the strata met with,—

Cooper or Orchard Coal, 8 feet; Soft Sandstone, containing a little slate, 63 feet: within the sandstone is, a bed of coal, 1 foot thick ; Patton and Bennett's Coal, 10 feet ; Supposed bottom coal—but this is doubted 12 feet, soft.

Pebbles and dirt generally underlie the Big Coal ; therefore the soft floor here is thought to prove that this lower bed is not the Big Coal.

The Avondale Tunnel is at present (1854) 155 yards long. It intersects two thin coal-beds. The first is a bed of heavy hard coal, from 4 to 5 feet thick ; the second, a bed one foot thick, but called 3 feet, and supposed to be the same as the 3-feet Coal *over* the Grand Tunnel mouth.

Watham's Coal, or Bennett's Coal on Watham's Creek, is worked N. of the anticlinal axis. This coal is 7½ feet thick, rather rough, but well adapted for smelting iron. The benches are,—

Sandy slate ; Good Coal ; Slate, 2 feet ; Good Coal, 2 feet 6 inches ; Slate, 7 inches ; Good Coal, 3 feet ; Shale.

The Tunnel is bored 30 yards into the coal ; the gangway runs E. and W. ; the dip, after passing in a little way, is very flat to the S.

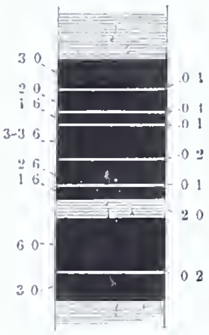


FIG. 309. — Reynold's (Smith's) Great Bed, 1 mile N. of Reynold's Tunnel.

Outcrops of the Coals.—The lines of outcrop of the four coals above described will be best understood by inspecting the Geological Map of the region. That of the large lower coal follows the bold outcrop of the Seral conglomerate, keeping a few hundred feet S. of it, winding a little in its course in virtue of the two or three flat anticlinal undulations which run obliquely off from the crest of the mountain, but deviating from a straight course chiefly from the influence of erosion, which swings the margin of the coal in every case S. into the beds of the ravines, and back again N. upon the water-sheds which separate them. The outcrops of the three next overlying coals are much more devious, in consequence of their greater and more complex displacements of level, by the lesser anticlinals already described as traversing them.

The following sections will assist to illustrate the undulations and places of outcrop of the coals in the vicinity of Plymouth.

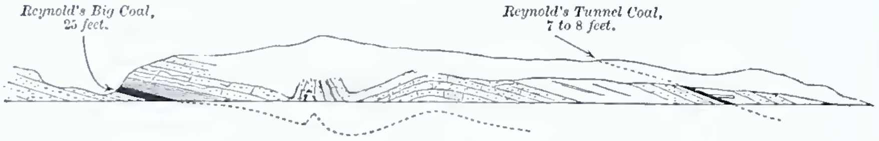

Reynold's Big Coal, 25 feet.
Reynold's Tunnel Coal, 7 to 8 feet.

FIG. 310.—Section on Smith's Creek, W. of Plymouth.—1 *inch* = 600 *feet.*

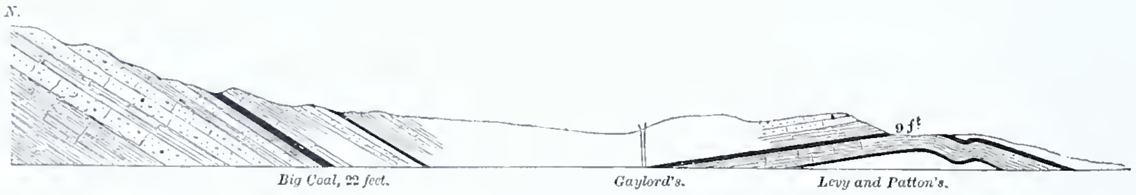


FIG. 311.—Section from Conglomerate by Gaylord's Mine, N. of Plymouth.

Upper Coal-beds.—There are probably two or more thin upper coal-beds above the Gould Bed, in the S.E. part of Ross's Hill, but of these we know at present extremely little, as they have not been developed by mining, and are not easily traceable without it ; the thickest of them has been penetrated in one or two spots just N. of the main road, and appears to be between 3 and 4 feet thick ; but what extent of surface it underlies has not been ascertained.

APPENDIX TO BOOK VIII.

BEING A REVISION OF PORTIONS OF THE SOUTHERN ANTHRACITE COAL-FIELD.

The following notes embody the results of an examination of all the collieries of the Southern Coal-field W. of Tuscarora, from which coal is at present mined, or may probably be mined in 1858. They bring the information down to the month of April of that year, and are more precise, therefore, than the memoranda embraced in the foregoing pages. In the chapters devoted to the description of the Pottsville Basin, special stress is laid upon the necessity of a full and complete understanding of the many anticlinal and synclinal flexures of the strata. Inferior importance is attached to the exact extent which a mine may have, or indeed to any features which do not throw some light upon the structure of the region. Our notes relating to the Collieries were in most cases obtained from the head miners, and are somewhat desultory and imperfect.

In collecting the information here presented, great care was taken that the data should be, as far as possible, correct. Recourse was had usually to some intelligent person connected with each mine, and, in a large majority of instances, also to the working plans. These sources, checked by our own observations and measurements, make the statements full, and, we think, precise, enabling us to point out some errors in previously expressed opinions, and to give many new facts, which the progress of mining in the district has brought to light.

TUSCARORA.

Tioga Colliery (page 108 of text) — Graber and Wagner, lessees; one-fourth of a mile E. of Tuscarora.— This mine has a slope, sunk 100 yards below water-level, on the Doherty or Jackson coal-seam—dip, from 50° to 65° S.; gangways are driven 600 yards E., and 300 yards W. From the foot of the slope a tunnel is cut 75 yards S. to the Stapleton Bed, upon which gangways are driven 150 yards E. and 30 yards W. A tunnel is driven N. from the gangway 50 yards E. of the slope, to a seam locally termed the Primrose Vein, dipping 45° S. Upon this bed gangways are opened 116 yards E. and 25 yards W.

The Jackson Seam, when undisturbed, will yield from 5 to 6½ feet of coal, but it is much pinched and crushed. It is the only seam now wrought at the colliery. The Stapleton Bed is very irregular, and subject to dirt-faults; it varies from 2 to 10 feet in thickness. The Primrose Seam, though stated to be 18 feet thick, has not yielded a ton of sound coal. It appears to be a mass of crushed coal and dirt, and 75 yards on the breasts above the gangway it is entirely pinched out.

Yield, in 1857, 14,612 tons.

Palmer's Tunnel (page 103 of text)—A. Sillyman, lessee (formerly, C. Sillyman).—A section representing the seams cut in this tunnel is already presented in an earlier chapter of the book (p. 106). We need only here notice the extent of the gangways. The *E.* Coal-bed is worked 250 yards E. of the Tunnel, and 2250 yards W.; its normal thickness is 18 feet; but 850 yards W. of the Tunnel it is supposed to be subdivided by the interpolation of a stratum of rock. The upper portion of the bed, 7½ feet thick, is mined forward. No attempt has been made to discover the true cause of the sudden diminution in thickness of the bed.

The Palmer Seam is mined 250 yards E.; driven 570 yards W. The coal was found abutting against a vertical wall of rock; along this the bed is shifted N., the bottom slate observing a gentle S. dip, whereas the top stands nearly vertical. The line of intersection of the two slates rises W. towards the surface, as has been proved by mining. The Palmer Bed has been traced on the surface 160 yards W. of the fault, but every attempt to follow it further has failed. The seam averages 10 feet of good coal.

The Bony, or Rough Seam, is mined 200 yards W. The bed contains from 8 to 16 feet of coarse bird's-eye coal.

The Grier Bed, driven 400 yards W., is nipped out by the approach of the top and bottom rocks; an upper level encountered the squeeze 160 yards further W. It is not now wrought, but its average thickness of good coal is 6 feet.

The shipments of coal in 1857 amounted to 32,318 tons.

Sillyman and Myers' Slope, and George H. Potts' Slope on Big Creek, were both abandoned in 1857.

Beechem's Upper Tunnel (page 110 of text)—R. Gorrell, agent.—This tunnel, entering Southward into Sharp Mountain intersects four seams of workable dimensions locally designated the O, P, Q, and the QQ, the several beds containing, according to the manager, 4½, 5, and 3 feet respectively of coal suited to the market. The only bed now wrought is the P seam, which is driven 700 yards E. and W. until it degenerates to dirt. The other coals have either been mined to the boundary of the property, or are too much crushed and irregular to be mined with profit. In 1857, 8559 tons were sent from the mine.

MIDDLEPORT.

Milford Colliery (page 113 of text)—J. Jones & Co., lessees (formerly S. Sillyman).—The information gathered in 1853 regarding the Milford Tunnel seems to have been imperfect as respects the distances between the seams. We are now possessed of the results of a correct mine survey.

The old Milford Tunnel is driven Southward 1410 feet to the Palmer coal-seam dipping steeply Northward. This tunnel was begun near the outcrop of the C. Pott Bed at water-level, and intersects the Palmer Seam, dipping S. 400 feet from the mouth; the Spohn, a thin leader, at 580 feet; and the Spohn leader of coal dipping steeply N. at 1270 feet. The gangways worked Eastward on the two dips of the Palmer seam converge 1650 feet from the tunnel. From the S. gangway of the Palmer, 420 feet E. of the main tunnel, a tunnel is cut Southward 160 feet to the sandstone seam, a thin bed dipping nearly vertically N. It is followed 950 feet E., and a third driven Southward intersects the rough seam at 175 feet; the C. Pott at 215 feet, and the Clarkson at 435 feet, all standing on end. The sandstone and the rough seams are not represented by any stratum of coal in the main tunnel at the N. side of the basin. The only seams now wrought at the colliery are the C. Pott, 2 or 3 feet thick, and the Clarkson, 5 feet thick. Upon these, gangways are driven a fourth of a mile Eastward.

The Milford Slope sunk on the Clarkson Seam, 1000 feet N.E. of the tunnel mouth, is now abandoned. From this slope the Clarkson was mined 650 yards E. and 425 yards W. The E. gangway encountered a "rock squeeze" of the coal, which ranged across the breasts 20 yards above the gangway. By a tunnel 55 yards long the C. Pott coal seam, overlying the Clarkson, was reached, and mined below water-level 225 yards W. and 260 yards Eastward.

The shipments in 1857 were 4303 tons.

Middleport or South Basin Colliery (page 115 of text)—Lessee, J. G. Bryce, (formerly Neville); Agent, H. C. Brooke.—The tunnel at this colliery enters Northward into Silver Hill, a distance of 20 yards, to a bed of coal, the precise equivalent of which has not been determined. It dips Southward at an angle of 20°. The coal is squeezed and faulty, for which reason the gangway to the Eastward was soon abandoned. West of the tunnel it was followed round the point of a declining saddle, upon the N. side of which the dip rises to 70°, and the coal is sound and good. Its thickness in the present workings averages 6 feet, though it sometimes exceeds this. There are no dividing-slates in the bed. The main gangway is 1100 yards long—ash, pink.

Yield of the mine, in 1856, 14,421 tons; in 1857, 14,704 tons.

A mile E. of the preceding a shaft was sunk upon a vertical coal-bed to a depth of 100 yards. From this level gangways ranged E. and W. a few hundred yards. The coal is 8 feet thick. It was worked only a few months in 1857 by Mr S. Chadwick, and is now temporarily abandoned. It yielded, in 1857, 1633 tons.

Five hundred yards S. of the shaft, Mr Bryce has recently opened a coal-bed 5½ feet thick, dipping from 60° to 65° Northward. The drift has advanced 180 yards.

CASCA WILLIAM VALLEY.

Northdale Slope Colliery (page 108 of text) — lessees, Luther, Daniel, and Gabel (formerly Rogers, Sinnickson, & Co.)—This mine is situated upon the Big or Raven coal seam, where it outcrops upon Mine Hill at the head of Casca William Valley. The prevailing subdivisions of this great White-Ash bed are as follows:—

Shelly Coal, 3 feet; Slate, 2 inches; Hard Coal, 7 feet; Slate, 6 inches; Hard Coal, 5 feet; Slate, 18 to 10 inches; Hard Coal, 4 or 5 feet.

At times the bed swells out to a thickness of 50 feet; but such enlargements are almost always followed by a corresponding diminution. It shrinks to 10 feet, and in one place to 7 feet thick.

The slope follows the bottom slate of the coal at an angle of 55°. Its length to the water-level gangways is 45 yards; to lower gangways, 100 yards farther. The water-level gangway is driven Eastward 1400 yards; a tunnel cut Northward into the mountain reached the coal 400 yards E. of the slope. The W. gangway at water-level is mined 650 yards. On the lower level the E. gangway is 120, and the W. 350 yards long. These gangways observe their proper course N. 70° E., and S. 70° W. In the W. workings of the lower level a crushed or faulty condition of the coal, commencing 20 yards W. of the slope, extends Eastward to the end of the E. gangway. The upper line of this "dirt" fault dips Westward 20°; it therefore crosses the slope, and affects the coal in the E. water-level gangway. The colliery is temporarily abandoned; but the obstacle opposed to profitable mining by this fault is thought to be nearly overcome.

In mining the coal from the breast between the levels, rectangular chambers 12 yards wide are cut away, leaving intermediate pillars of coal 6 yards wide to support the roof. These pillars are abstracted when the level is abandoned, and the roof falls in. In order to protect the slope-way of the mine from injury, pillars 40 yards wide are left on either side.

The old water-level *Tunnel* above alluded to is 546 feet long to the Big Coal, the gangways upon which drain off the water. The tunnel cut a coal-seam 8 feet thick, known as the Black Valley bed 207 feet S. of the Big seam. Three small coals were passed between this and the mouth. None of these have been mined.

Raven Slope, Casca William Colliery—(Luther, Daniel, and Gabel).—The old workings comprised a water-level gangway W., and a slope-level with gangways E. and W. The water-level gangway or drift was mined 775 yards W. to the property line, and is now abandoned. The old slope (exhibited in the Casca William section) was located on the sharp anticlinal Axis (D) of the Big or Raven Coal over the E. end of the South Mine Hill Axis. It followed the bottom slate of the coal, descending Southward at an angle of 61° a slope length of 270 feet. The coal then became flat, and rose with an opposing dip to roll over again into S. dip, thus forming a basin 50 feet wide, and an anticlinal arch, which was passed through by a tunnel 90 feet long. The gangways in the basin were mined W. 775 yards. The E. gangway was driven 175 yards, when it began to warp Northward round the declining anticlinal on which the engine-house stands. At 200 yards' distance from the slope the level was abandoned. From the S. end of the tunnel the W. gangway, 185 yards long, swept round the end of the little anticlinal roll, and connected with the main gangway W. from the slope. The E. gangway started from the tunnel on coal dipping 29° S.; but the saddle declined E., and the basin rose, so that the two merged into a nearly flat dip. The gangway swung Northward, and was abandoned: it is 150 yards long.

The new Raven Slope descends through sandstone at an angle of 52°, to intersect the Big Coal at the South end of the tunnel from the old slope. It is 120 yards long to the tunnel level. It then follows the coal 102 yards below the tunnel-level at an average angle of 60°. At this lower level the W. gangway is driven 350 yards in the normal bearing. The E. gangway, 75 yards E. of the slope, deflects S. round a feeble basin, and again turns E. It will, no doubt, eventually deflect N., parallel to the old levels above. The length of this gangway at present is 260 yards.

The great bed mined at this colliery exhibits the same character, subdivisions, and average thickness, which we have noted in describing the Northdale Slope.

The *Black Heath Coal-bed,* lying next above the Big Seam, has been mined above water-level only. It is 9 feet thick, including an 8-inch band of slate 5 feet from the top. The ash is pink.

The *Black Valley Seam* next succeeding has not been mined below water-level. It is a pink ash coal, 7 feet thick, divided by 1 foot of slate 4 feet from the top. The proprietors propose erecting a slope colliery upon one or other of these beds.

The *Luther Slope Mine,* belonging to the same estate as the preceding collieries, is located upon the Luther or Diamond Coal-bed, which averages 6 feet in thickness ; top bench, 4 feet ; slate and dirt, 6 inches ; bottom bench, 18 to 36 inches.

The slope descends along the bottom slate 90 yards, at an angle of 50° to the first level. The dip thence gradually declines to 26° at the lower level ; total length, 415 feet ; perpendicular depth of lower level, 282 feet.

At the upper level gangways are driven E. and W., and a tunnel cut Northward. This tunnel, which is about 150 yards in length, intersects three coal-seams dipping Southward. The last of these, known as the " Joe Wright Vein," saddles over into N. dip, and is cut at the end of the tunnel just at the level of the synclinal next N.*

The *Lyon Coal,* divided into two benches by 8 inches of bony or impure coal, is 6 feet thick at an average. The Pasco is 6 feet thick, and the Wright has 3 feet of good coal. The latter turns flat on the axis 30 yards above the tunnel, and dips Northward 45°. It is mined only 70 yards up the long breast N. of the basin.

From the tunnel-level the E. gangway on the Luther Slope Coal is 900 yards long ; the W. gangway, 774 yards. The Lyon bed is worked 450 yards W. of the tunnel, and 75 yards E. The Pasco, 250 yards W., and 60 yards E. The Wright coal on its first S. dip 35 yards E., and 75 yards W. This W. gangway deflects Northward upon West-dipping coal, indicating a gradual falling away of the saddle in that direction. On the S. dip of the basin the same bed is mined 400 yards W., and 40 yards E.

The lower slope-level is mined W. 774 yards, and E. 2000 yards.

The slope is now being extended to begin another level 100 yards lower. Its total length will then be 515 feet.

All the beds mined at this colliery yield Red-Ash Coal.

The yield of the Casca William collieries in 1856, from the Black Valley water-level drift and the Luther Slope, was 45,177 tons. In 1857, the product from the Raven Slope for 9 months—the Luther Slope, 12 months —and a small gin-slope mining surface-coal, 6 months—also the West Delaware Mine on W. Norwegian—was 39,399 tons.

None of these mines are shipping coal.—(March 1, 1858.)

Novelty Colliery, near New Philadelphia (page 125 of text) — Lessee, George Rickert, (formerly, Connor and Rhoads).—A slope-mine upon the Spohn Coal-bed dips Southward 35° ; length, 750 feet ; three levels below water-line ; the two lower levels are 300 feet apart. The upper and middle slope gangways are now abandoned. They were mined 900 yards W., and 500 E. The lower level now worked is 400 yards E., and 300 W. The upper levels E were abandoned because of a fault in the coal, bearing South-eastward.

The Spohn seam averages 4 feet 6 inches of coal. It is overlaid by 9 feet of slate, which forms the bottom of a smaller bed 3 feet thick. This has been reached by short tunnels cut from the Spohn gangways, and is mined parallel with the latter.

---

* An error will be detected in the Casca William Section, illustrating the structure and number of coal-seams at this point. The progress of mining subsequent to the construction of that Section, has shown that the beds noted at the outcrop as the Lyon, Pasco, and Joe Wright seams, are the same which have been cut in the tunnel successively beneath the slope coal. The lowest of these, after forming a basin at the tunnel-level, rises gently Northward, and at or near the surface, rolls over an axis, and into a basin, both between the Axes D and E of our Section, from which it emerges to crop out where we have placed it. These last flexures are not shown in our Section, and will account for the seeming great distance of the Wright below the Pasco bed.

The yield, in 1857, was 30,667 tons.

Bare Ridge Colliery (page 127 of text)—Lessee, John G. Hewes, formerly Oliver.—Situated on the S. side of Bare Ridge opposite Cwmbola. Slope on the tunnel vein S. dip 30° at top, increasing to 41° at bottom; length, 865 feet to lower level; below water-line, 585 feet; three levels—the first 225 feet below water-level; the two lower 180 feet apart. The first lift is worked out and abandoned. The lower level is mined 450 yards E. and 400 yards W.; the middle level, 300 yards E. and W. A dirt-fault, 100 feet wide, crosses the E. gangways obliquely, bearing South-eastward.

The coal mined at this colliery burns to deep red ash. The bed between slates is 5 feet thick; though of good coal, between 3 and 4 feet only is mined. There are three benches in the seam, the upper and middle usually separated by 5 or 6 inches of bony coal.

The yield, in 1856, was 20,186; in 1857, 22,194.*

Silver Creek (page 120 of text).—There is an important error in the section upon Silver Creek which we wish here to correct. By referring to the passage, the reader will perceive an interval of 500 feet is represented as existing near its Northern end between what is indicated as Dodson's Orchard, and the small coal-seam next below the Slope coal called the N. Diamond. This interval should be eliminated by shifting the Southern part of the section Northward, so that the Slope coal occupies the position of the Orchard, and the bed next below it the position of the Primrose. Making this correction, it will at once appear that a modification of the nomenclature is necessary, and we are compelled to regard the Primrose Coal as the proper equivalent of what we have called the North Diamond. Any corrections or deductions based upon this error in our section will at once suggest themselves. Thus the total number of the coal-beds must be reduced by two, and a change must be made in the synonyms of the Silver Creek Coal-beds.

Madison Colliery—G. J. Jones (formerly Beatty & Co.)—The great Chadwick White-Ash Coal-bed (mined in 1853 by Guiterman & Co.) is that upon which the operations of this colliery are based. On Silver Creek no change of dip is observable between the Chadwick bed and the Tucker Slope coal. If, notwithstanding this fact, the seams be regarded as identical, we must infer that there is at this point a sudden and sharp inversion of the strata, or a fault along which the Tucker bed has been upheaved without leaving any trace of North-dipping strata.

At the Madison Colliery two drifts enter the Chadwick bed at different levels on the breast. The subdivisions of the seam are as follows:—

		Feet.	In.			Feet.	In.
"South Vein."	Coal, . . .	12	0	"North Vein."	Coal, . . .	5	0
	Bony Coal, . .	1	6		Slate, . . .	0	3
	Coal, . . .	4	6		Coal, . . .	0	2
					Slate, . . .	0	6
	Slate, . . .	5	0		Coal, . . .	5–6	0

This is the average character of the bed. Within the mine, about 700 yards E. of the entrance on the upper level, the 5 feet bed of slate disappears by thinning away, or is lost in the confusion of the bed which is crushed and broken, owing to a circumstance to which we will presently advert. This confusion of the bed extends 300 yards E. from where it is first encountered; after which the lower division seems permanently enlarged, and the whole bed is sound.

The two drifts follow the bottom slate of the lower division E., and short cross tunnels through the dividing-slate give access to the upper member or S. vein. The dip at the mine mouth is 40°; this gradually declines to 25°, and rises to 60° in the E. extension of the workings. In the upper level the breasts, ascending both the upper and lower seams, cut through coal, dipping nearly vertically N., and then pass into conglomerate in the former case, and slate in the latter. These breasts became successively shorter, and at 600 yards in the one case, E. of the drift mouth, and at 650 yards in the other, the rock came down to the gangway level. The facts thus stated lead at once to the inference that the small anticlinal roll (D), indicated in our section as affecting the second coal-seam below the Chadwick Double Bed, declines towards the E., and causes the great bed to fold over and around it into nearly vertical N. dips. It is for this reason that the breasts became successively shorter, and encountered the wall of slate and sandstone. The sharpness of the turn causes the confusion in the bed at the point of the saddle on the gangway level, while the slowness with which the crest of the arch droops away E. gives rise to the great expansion of the coal at that point. The somewhat exaggerated thickness assigned to the bed in the text (page 120) is due to this abnormal mass of coal.

---

* Agard and Tyler's Slope at Cwmbola, also that of the same operators at Belmont, Colahan's Shaft, near Cwmbola, and the old Salem Slope at Young's Landing, near Pottsville, are all worked out and abandoned.

A cross-cut from the axis of the saddle cut N. 60 yards, crossed a basin of the coal which rises W. and into regular S. dips ranging E. The rise W. of this basin is proved by the gangway W. from the N. end of the tunnel; in this the coal became soft and crushed, and opposing dips were found. The gangway, E. from the N. end of the tunnel, met the main gangway prolonged from its S. end.

The only effect of this declining saddle and rising basin in the lower gangway is to cause some variation in the slope of the breasts, until, as the gangway advances E., the breasts from it are worked out to the outcrop without interference. The upper coal in this lower level is nipped out by the approach of the top rock to the bottom slates, 1100 yards E. of the mine mouth. The gangway on the lower division is 1450 yards long.

From the lower level the coal was followed down the dip at an angle of 25° to a distance of 38 yards, when the top rock came vertically down, and the seam was entirely cut off. This may be due to a fault with an upthrow which has elevated the coal far above water-level at the Tucker Slope Colliery, in accordance with the views of those who regard the seams as identical, or, what is more probable, as a simple crushing-out, with perhaps a trivial dislocation of the bed.

The Madison Colliery, in 1856, shipped 38,431 tons of coal; in 1857, 22,061 tons.

Guiterman's Colliery (page 120 of text)—Lessee, H. Guiterman & Co.—The next seam below the Chadwick Bed mined at this colliery is also a white ash coal, subdivided as follows:—

Coal, from 5 to 6 feet; Slate, 1 foot; Coal, impure, 3 feet.

The anticlinal and synclinal flexures alluded to in describing the Madison Colliery, have affected this bed in a precisely similar manner. The water-level gangway, driven E., encounters faulty or crushed coal 500 yards from the mine-mouth, and about the same distance W. of the similar disturbance in the Chadwick Bed. The gangway was prolonged, through this and across the adjoining crushed basin, into sound coal on a regular S. dip of 45°.

The middle level was abandoned when it reached the point of the saddle. The upper level is a drift working out coal from the S. dips of the basin. Aggregate length of gangways, 2400 yards.

This colliery yielded, in 1856, 20,700 tons; in 1857, 15,636 tons.

Silver Creek Colliery (page 121 of text)—Lessee, John Tucker.—This is a Slope mine, descending S. on the bottom slate of the "North Vein," at an angle declining from 60° near the top to 40° at the bottom. Length of slope, 447 feet; below water-level, 297 feet.

The thickness of the bed is very variable; it is estimated to yield 10 feet of coal, subdivided as follows:—

Coal, 4 feet 6 inches; Slate, from 4 to 12 inches; Coal (blacksmith's), from 20 to 24 inches; Bony coal, from 6 to 9 inches; Coal, 5 feet.

From the foot of the slope a tunnel is cut S. 25 feet through slate to the "South Vein." This seam is 30 feet thick, but crushed at the tunnel in the E. gangway. Its normal subdivisions are,—

Bony Coal, 3 feet; Slate, 9 inches; Coal, 1 foot 6 inches; Slate, 2 inches; Coal, 2 feet; Slate, 2 inches; Coal, 1 foot 6 inches; Dirt and slate, 1 foot 3 inches.

The slate division between these two beds—the "North and South Veins"—increases at the water-level going E., from 6 inches to 30 feet. In the slope gangways a similar gradual enlargement occurs, amounting to 50 feet of strata, requiring a tunnel 126 feet long between the two seams, at a point 500 yards E. of the slope.

The slope gangway E. on the lower coal is 1500 yards long, on the upper beds 1000 yards. The presence of a synclinal trough rising W. causes a slight deflection in the gangway on the upper coal W. of the tunnel above alluded to. This basin is probably the W. prolongation of that encountered in the Old Raven Slope on Casca William.

The W. gangway from the tunnel is now abandoned, the coal having proved faulty.

The yield, in 1856, was 69,554 tons; in 1857, 34,641 tons.

Neill's Slopes on the N. Diamond (Primrose) and S. Diamond (Orchard) seams, were both abandoned early in 1858. The first is about 200 feet long, the latter 591, dipping 35° to 45° S. A tunnel driven N. from the gangway of the Orchard Seam cut the Primrose Bed in 210 feet, and the Holmes in 375 feet. The anticlinal (E.) ranges 205 feet N. of the latter.

Diamond Colliery—J. M. Lewis & Co. (formerly Winterstein); in 1853, Chadwick & Co.—A slope is sunk on the Gin Seam at an angle of 55° S. on the S. side of anticlinal axis G., and W. side of Silver Creek. Length, 120 yards to lower level. Upper level, 60 yards from the surface. The upper gangway is driven 100 yards E. and 1000 yards W. From the gangway, 40 yards W. of the slope, a tunnel is cut 30 yards Northward to the Diamond Seam, upon which a gangway is driven 1000 yards W.

The lower gangways are recently started. The Slope coal averages 10 feet 6 inches in thickness; the Diamond, from 4 feet 6 inches to 6 feet. Both seams were somewhat crushed and dirty in the breasts.

In 1857, 7591 tons were mined and sent to market.

ZACHARIAH'S RUN.

Oakdale Colliery (page 128 of text)—Valley Furnace Lands, Windy Harbour—Lessees, Whitfield & Dornan.—Slope Mine sunk on the N. dip of the Diamond Coal at an angle of 65°. Length, 105 yards; below water-level, 83 yards. The Diamond Vein is subdivided by a slate band, 3 inches thick, into an upper bench 3 or 4 feet, and a lower 2 feet thick. Upon it gangways are working E. and W. In the E. gangway, 50 yards from the Slope, the coal is compressed to 18 inches thickness, for a distance of 15 yards, by the approach of the top and bottom slates.

From the foot of the Slope a tunnel is driven N. 33 yards to the Primrose Seam. The thickness of this bed has not been yet proved, nor have any gangways entered it.

The yield in 1857, from two months' mining, was 1356 tons.

Windy Harbour Colliery—Bowman & Co. (formerly S. Sillyman).—This slope, situated at the head of the valley of Zachariah's Run, is sunk 100 yards on the Skidmore Seam at an average dip of 60°. From the foot of the slope a tunnel is cut Southward 117 feet to the Mammoth Bed, also dipping steeply S. This seam at the tunnel is 20 feet thick, in two main divisions, separated by 2 feet of slate. This slate grows thicker going E.; and within 100 feet from the tunnel it gives place to a stratum of sandstone, which completely divides the coal into a lower seam 10 feet thick, and an upper 12 or 15 feet. The gangways following the two divisions of the coal diverge gradually, and 1400 feet E. of the point of separation are 95 feet apart. At this point the S. gangway deflects Southward for 100 feet on faulty coal, dipping gently Westward, and then turns E. The N. gangway pursues a normal direction until influenced by a W. dip which deflects the gangway Southward. The coal at this point is shelly and impure. The Slope coal is 10 feet thick, including several slate divisions. The average amount of coal is 7 or 8 feet. It is mined 800 feet E. from the Slope.

The yield of the Colliery, in 1857, was 13,870 tons.

E. RAVENSDALE.

Lawrence Grove Colliery (page 130 of text)—R. M. and L. Lewis's Tract, in the valley of E. Ravensdale—Lessee, William Price.—This is a drift-mine working E. upon the Primrose Bed, or Fitzimmon's Coal of Zachariah's Run, dipping 36° S. from the fifth anticlinal S. of Mine Hill. Its thickness is variable, between 8 and 14 feet; average, 10 feet; it is in two benches, separated by a dirt-parting. Length of gangway 800 yards, and about 250 yards from an old gangway driven W. from Zachariah's Run; breast on coal 50 or 60 yards. A tunnel is cut 61 yards Northward from the gangway, 50 yards E. of the entrance to the Holmes or Henderson Coal, which is

5 feet thick, in two benches. This has not yet been mined to any extent. Immediately N. of the outcrop of the Holmes Seam, an anticlinal (H) passes, which causes that bed to turn over into steep N. dips. The Primrose Bed has been mined towards the W. from Zachariah's Run on the nearly vertical N. dip of this saddle, by J. J. Williams, who obtained from it, in 1857, 4524 tons. A slope will probably be sunk at Price's Colliery at an early day.

In 1856, Mr Price mined 6967 tons; in 1857, 22,649 tons.

In the valley of Zachariah's Run, Mr John G. Hewes of Pottsville, in the year 1856, conducted a boring, which was made from the water-level on the fifth anticlinal S. of Mine Hill (H), beneath the arch of the Brooke Seam, now regarded as the equivalent to the "Seven-foot Vein" overlying the Mammoth. This boring, 93 feet deep, cut a large coal. A slope was subsequently sunk 100 yards on the Brooke Seam, dipping N. 80°, and a tunnel driven S. 74 feet to the Mammoth. Where cut by the tunnel, this bed was only 4 feet thick, but it widens out in the breasts to 25 feet. A colliery will be established at this point.

CROW HOLLOW.

Rainbow Colliery (page 131 of text)—Kirk & Baum (formerly S. Sillyman).—These mines are exclusively above water-level. The present gangways are entered by a tunnel driven Northward from the valley of Crow Hollow, about half a mile E. of Snyder's Mount Hope Slope. This tunnel is 400 feet long to the 7-feet coal, and is prolonged with a slight change of direction to the Mammoth Bed. Upon both of these beds gangways are driven Eastward a great distance. The coals possess their average dimensions, and dip 10° S. at the tunnel. In the W. gangway the 7-feet bed is faulty and impure. The workings upon the Big Coal have warped around a declining anticlinal, that likewise affects gangways of the Mount Hope Mine, and into the rising basin next N. of it. It is to be observed regarding these curvatures of the gangway, that the effect of the rapidly-rising basin is to cause W. dips, while the saddle will fail to present decided N. dips, merely causing, in miners' language, a "throw" of the vein to the Southward. The flexures are traceable as more important rolls of the strata farther Eastward.

A few hundred feet N.E. of this point a tunnel is cut Northward 85 yards from the outcrop of the Big Coal to what is known as the Skidmore Seam. In the gangway the coal is pinched down to 18 inches, and the mining in that direction was abandoned. Eastward the coal is thin for 10 yards; it then enlarges, and the gangway is driven upwards of 1½ miles. The thickness of the bed varies from 6½ to 8 feet, and it is underlaid by 3 feet of dirt and slate.

The yield of this colliery, in 1856, was 65,871 tons; in 1857, these mines, and the Carey Slope to be described, yielded together 90,888 tons.

Crow Hollow.—Sawmill Tract (page 131 of text)—M. C. Diehl's Drift follows the Holmes Bed 600 yards Eastward. The average thickness of coal is 5 feet 6 inches in two benches, sometimes separated by 2 inches of bone coal. Dip 32° S. at the drift-level, declining to 20° in the breasts. Length of breasts, 60 yards. The yield, in 1856, was 8629 tons; in 1857, 6621.

Near the outcrop of the Primrose Bed, 60 yards S. of Diehl's Drift, a boring was made in 1853 upon the lands of the North America Company. The notes of this boring are already presented on p. 134.

MILL CREEK.

Eagle Colliery (page 132 of text)—Lessee, William H. Jones.—The great White-ash Coal-seam, lying near the base of the Coal-measures on Mill Creek, is wrought at this colliery by slope and water-level drift. The drift enters upon a bed commonly called the "Seven-foot," which is separated from the great bed by from 6 to 9 feet of slate. The following section represents these beds:—

Coal streaked with slate, more or less impure, 6 to 7 feet; Slate, 6 to 9 feet; Coal, 5 feet; Coal, 7 feet; Slate, sometimes absent, 2 feet 5 inches; Coal, 2 feet; Coal, 7 feet; Slate, 5 inches; Coal, sometimes dirt and slate, 2 feet.

From the gangway on the "Seven-foot Bed," the underlying big coal is entered by tunnels cut through the dividing-slate. The dip at the drift entrance is 25° S.; this gradually increases E. until the coal stands vertically, but it gradually declines again while the direction of the dip changes, and the gangway, following the bed, warps round the basin of the coal at a distance of 4800 feet E. After making this turn the gangway ranges W., nearly parallel to its former course upon the opposite or S. side of the basin. At this level the basin is 300 feet wide. The presence of an anticlinal (probably the true axis D of Silver Creek and Casca William, if we regard axis D of the Mill Creek Section as local), lying S. of the basin and sinking W., causes the gangway to sweep S. and E., while the coal dips at a low angle to every point of the compass, from N. to W. and into the regular S. dip of the anticlinal. The latter curvature is 2200 feet W. of the former. Passing this, the gangway observes its normal direction towards the E. Along the line of the basin and saddle rising gangways follow the coal E. towards the outcrop.

The slope descends S. on the bottom slate of the Great Bed 573 feet to the lower level; to the upper level, 311 feet. The angle of dip declines from 27° at the top to 11° at the bottom. In sinking this slope a serious disturbance in the strata was encountered, which for a time impeded profitable mining. About 150 yards from the top of the slope, the great bed, which had hitherto held its normal thickness, was found compressed by the approach of the overlying and underlying strata. This thinning of the bed continued until at length the seam had entirely disappeared, or its horizon was indicated only by a thin streak of black dirt. The lower portion of the slope, therefore, is cut through rock. From the foot of the slope the leader was followed about 50 yards E., when the top and bottom diverged, and the bed resumed its normal dimensions. The course of this "nip" is S. of E. A similar trouble occurred in Chillis's old water-level gangways upon the same seam on the W. side of Mill Creek, and caused the abandonment of those mines. The lower-level gangway from the slope is mined E. about 1800 feet. At that distance it encountered a wall of rock running obliquely across the gangway in a direction N. 20° E., the face of which dips towards the gangway at an angle of 30°. Approaching this the coal becomes confused and contorted. The coal rises along the face of this rock 20 feet, though diminished in thickness, and on top of it lies nearly horizontal. Followed E. from the fault which we have indicated, the bed is completely nipped out in 200 yards by the approach of the top and bottom slates.

The anticlinal roll which we have noticed as causing a curvature of the water-level gangway on the big coal, descends so rapidly W. as to leave no indication of its presence at the slope; but about 1500 feet E. of the slope it causes the upper-level gangway to branch—one part following the very gentle N. dip of the saddle, the other its W. and S. dips. The latter gangway has recently encountered the same rock-fault previously noticed as causing a stoppage of the lower level. At this point the rock dips 60° N. to 80° W. at the gangway level. As in the former case the coal is confused, and rises along the plane of the rock, but under what thickness, and how far, has not yet been determined. An attempt is being made to follow the coal in the hope that the upheaval has not injured its quality on the level of the upthrown portion.

It is to be observed that the bearing of this fault intersects the range of the strata at an angle of about 50°. Its line must therefore cross the saddle; but it seems to have caused no disturbance in the drift-level, before reaching which its effects must have expired. We have not sufficient data to guide us to a full understanding of the nature and extent of this curious disturbance in the strata.

The yield of this colliery, in 1856, is reported at 83,712 tons; in 1857, 88,040 tons.

The seam underlying the Johns Bed, locally known as the Skidmore, was wrought in 1857 by J. Schlotman & Co., from a drift above water-level. It is $4\frac{1}{2}$ or 5 feet thick, and yielded 5099 tons. A bed occupying the same relative position to the Big coal on the N. side of Mine Hill dipping N., was wrought by W. J. Uhler, and produced 5260 tons.

Pine Forest Slope (page 132 of text)—Lessee, George W. Snyder (formerly, Snyder & Milnes).—This colliery is situated upon the Great Mammoth Bed, and its overlying contiguous coal-bed, known as the Seven-feet coal. The former of these presents the following average subdivisions:—

Slate and coal mixed, 2 to 3 feet; Good coal, 4 feet 6 inches; Parting, sometimes thin slate; Hard good coal, 7 feet; Parting; Hard coal, 5 feet; Slate and dirt, 1 foot; Hard coal, 7 feet; Slate, 6 inches; Coal, sometimes soft, 2 feet 3 inches.

This will represent the condition of the bed under favourable circumstances at the several Mill Creek

Collieries, where it is mined. The Mammoth Bed is overlaid by a stratum of slate, from 7 to 9 feet in thickness, upon which reposes the "Seven-foot Vein." The several parts are as follows :—

Good coal, including a thin variable slate, 2 feet; Parting; Good coal, 5 feet; Slaty and bony coal, 8 feet 10 inches; Rough coal, 1 foot 6 to 2 feet.

The Pine Forest Slope descends S. at an angle of 17° upon the bottom slate of the Mammoth Coal Bed for 650 feet, and deflects 30° E. to keep within the line of the property; length between levels, 380 feet—total, 1030 feet. The sump gangway, to be used as a water reservoir, encountered the basin of the coal 150 feet from the foot of the slope. This basin, ranging E. in the bearing, N. 72° E., and rising in that direction, causes the upper level gangway E. to curve S. round the end of it; S. of the basin the presence of a partially-developed anticlinal roll in the coal drooping W. causes a reverse curve in the gangway, which there observes its normal direction. The deflections occur half a mile W. of the slope. From the upper gangway the top slate is cut through one-third of a mile E. of the slope, and a gangway is driven on the Seven-feet coal-bed.

The lower level gangway is influenced by the same basin which affects the upper level in a similar manner; it will eventually sweep round to the E. parallel with the upper workings. The upper level is 5000 feet long, and is now abandoned. No gangways have been driven W. from the slope.

The *Mount Hope Slope Mine* is situated one-third of a mile E. of the preceding, and conducted by the same person. It follows the bottom slate of the same great seam at an angle of 23° S. 13° E. to the basin of the coal; length to the basin, 720 feet. In prolongation of the direction of the slope, an inclined plane on the opposite dip rises at an angle of about 15° for 200 feet, and is continued as a slowly rising gangway until, passing the crest of the saddle previously noticed as affecting the upper gangway of the Pine Forest Slope, it curves W. and ranges along the flank of the arch. At different levels on the rising gangway, roads are run off to the E. From the foot of the slope, and from a higher level on the rising plane, gangways diverge S.W., which curve concentrically around the saddle, returning into the main avenue. In several parts of the mine short tunnels are cut into the Seven-feet coal, upon which gangways are driven.

A gangway cut E. from the foot of the slope rose towards the surface with the W. dip of the coal, but at 800 feet distance was impeded by a rock-fault. Air-courses are run up the breasts of the coal at convenient points, by which the mine is ventilated. The total length of the gangways in this mine is about 3¼ miles.

St Clair Colliery—Lessees, William Milnes & Co. (formerly Pinkerton).—This slope mine descends upon the Mammoth Coal-bed on the W. side of the valley of Mill Creek in range with the Pine Forest Slopes. Its length slightly exceeds 1200 feet, inclined S. at an angle of 23° at the top, but becoming nearly flat at the bottom. There are three levels of gangway in the mine—the first 500 feet from the top, the second 250 feet lower; none of these are mined to the E. The upper-level gangway, W., has worked out nearly all the coal above it as far W. as the property line. The two lower levels have not advanced far. The lowest gangway ranging W., deflects S., owing to the nearly flat dips of the basin of the coal. The water-level drifts upon the overlying Primrose Coal-bed were similarly affected. The thickness of the Big coal and the Seven-feet is normal at the slope, though the latter is faulty; but followed W., the Big coal dwindles to 15 feet, while the Seven-feet increases to a thickness of 15 feet, the quality of the coal not deteriorating.

The yield of this colliery, in 1856, was 123,128 tons; in 1857 it fell off to 81,135 tons.

Carey's Slope Mine—(Lessees, Kirk & Baum).—This slope is 650 feet W. of the Pine Forest Slope, and descends upon the same Great Mammoth Bed upon the adjoining tract; length, 834 feet, inclining Southward 24° at the top, declining to 14° below. The gangway W. from the slope is 1000 feet long. Eastward, two gangways are laid out, one following the bottom slate of the bed, the other keeping immediately beneath the top slate; from the latter an air-way descends along the dip of the coal at an average angle of 15° to the E. gangway workings from Carey's Shaft. In one part of this air-way a local upward bulge in the roof-slate causes an increased thickness of the bed. The two Eastern gangways above alluded to converge in working horizontal coal, from which point the main gangway turns Southward on the W. dip of the bed, and finally sweeps to the

Eastward upon its regular S. dip. From the top of the slope a short tunnel is cut to the overlying 7-feet coal, upon which gangways and breasts are mined out in the usual manner.

Carey's Shaft Colliery (page 133 of text)—Lessees, Kirk & Baum.—A perpendicular shaft is sunk, cutting the Primrose, Holmes, and several trivial beds, and the 7-feet and Mammoth seams to the bottom slate, of which the depth is stated to be 435 feet. The last two beds only are mined. They present the usual subdivisions and thicknesses proper to them in the district, as we have previously stated them. The average of good coal is 16 feet in the large bed, and 7 feet in the smaller seam. The gangways observe a normal direction from the shaft Eastward 1000 feet, and Westward 700 feet. In the latter direction the dip of the coal does not exceed 10° S. Two tunnels are driven to the 7-feet bed, upon which gangways are laid out.

Primrose Slope (page 134 of text)—Lessee, F. J. Parvin.—The slope follows the bottom slate of the Primrose Pink-Ash Coal-seam 100 yards to the first level at an angle of 20°, and 65 yards at a dip of 15° to the second level, at which the coal turns flat for 20 yards, and then dips Southward at an angle of 8°. The coal-bed averages 14 feet in thickness in two benches, without dividing-slate; parts of the lower bench are occasionally somewhat bony. The upper level is worked 140 yards E., and 600 yards W. The lower level follows the horizontal coal 120 yards E.; the coal becomes soft in that direction. This flattening of the seam is due to the rise of two small basins, which, as they sink Westward, cause the gangways to diverge in that direction. The Southern gangway occupies the centre of the Southern Basin; it is 200 yards long. The breasts on the bottom slate of the coal rose from this 15 yards S., and 5 yards N., at both of which points the strata roll over into contrary dips. The Northern basin was followed by a slope, but the influx of water caused its abandonment. The Northern gangway on the main slope breast of the coal is at present 300 yards long. The breasts from it extend to the upper gangway level, an average distance of 50 yards.

This slope raised, in 1856, 25,330 tons.

In 1857, this colliery, and a Red-Ash slope-mine to be described, leased by the same party, yielded, with five months' working, 19,846 tons.

Lewis Red-Ash Colliery (page 135 of text)—Lessee, F. J. Parvin.—A slope-mine on the bottom slate of the Peacock Coal-bed 100 yards below water-level. Coal, 6 feet thick; dip 45° S., increasing to 50°. This seam has been worked out. From the gangway, 200 yards W. of the slope, a tunnel is cut Southward 40 yards, through rock and slate, to the Clinton Coal, 3 feet thick. Dip 50°; upon which a gangway W. is 600 yards long. The tunnel, prolonged 62 yards through rock-slate and two small coal-seams, intersects the Big Tracy, and is to be extended to the Little Tracy, which it is expected to strike near the basin. The Big Tracy, where it was cut by the tunnel, is 20 feet thick, but shelly and impure. Its uniform normal thickness varies between 6 and 8 feet, including 2 feet of bony coal; the latter is not always present. Dip, 50° S.; gangway, W., 200 yards long.

Production, in 1856, 17,296 tons.

Lewis Red-Ash Colliery, E. side of Mill Creek (page 135 of text)—George W. Snyder's (formerly, Snyder & Milnes).—The slope is sunk upon the Lewis Coal-bed, dipping S. at an angle of 30° to 32°. Length, below water-level, 84 yards; to water-level, 33 yards; gangway E., 1800 yards. 170 yards E. of the slope a tunnel is driven N. 165 yards, by estimation of the mine captain, through slate and rock to the Yard coal, which has been worked E. to the line. The tunnel is prolonged 50 yards Northward to the Spohn Bed, which was found in fault; a second tunnel is therefore cut to this, 400 yards E. of the former; the coal still proves faulty, though a limited amount of good fuel has been taken from it.

The Lewis Seam is 4 feet 6 inches thick, and is not subdivided by any persistent slate-bands. The Yard coal is nearly 3 feet thick. Both these beds are subject to irregularities arising from the approach of the top and bottom slates on the one hand, or from mere degeneracy into black crumbly dirt on the other. The frequent recurrence of these conditions in this, as in many other mines, has sadly interfered with the profits of the colliers.

A new lift of 90 yards is about to be sunk upon the Lewis Bed.

EAST NORWEGIAN.

Flowery Field Slope, N.W. of Wadesville (page 146 of text)—Wasley & Co.—This slope is sunk at an angle of 37° obliquely upon the bottom slate of the "7-feet Vein," the true dip of which is 44° S. It is 684 feet long. The Slope coal at this mine presents the unusual thickness of 12 or 14 feet. It has been worked 1100 feet E. from the slope. The slate, 12 feet thick, dividing this bed from the Mammoth Seam, has been cut through by a short tunnel 150 feet E. of the slope; and a gangway is driven E. 500 feet upon the latter. The Mammoth Seam is 25 feet thick. The colliery is not now worked. In 1857, Treck & Spencer shipped coal from it during a part of the year.

Flowery Field Tunnel—Lessee, Mr James (formerly George Mason).—This tunnel is driven Southward 310 feet to the Flowery Field or Orchard Coal-bed, dipping gently S. The bed is from 5 to 5 feet 6 inches thick. Over the top slate, which is 4 feet thick, a 3-feet bed of coal is wrought from this tunnel. From the gangway, 200 feet W. of the tunnel, a cross-cut extends 200 feet Southward through nearly flat coal and rock occupying the central parts of the basin to the N. dip of the same beds. The gangways Westward from the two ends of this cross-cut converge and unite in 350 feet. Gangways are cut in various directions through the coal occupying the basin, until about 750 feet W. of the convergence of the gangways they are affected by the deepening of a basin, the axis of which is nearly in line with this basin, rising Westward; this causes a divergence of the gangways. The Southern branch deflects Southward upon the W. end of the drooping anticlinal that passes between the old slopes on the North and South-dipping Primrose Coal.

An upper-level drift on the breast of the Flowery Field bed, 600 feet N. of the tunnel gangway, is worked half a mile Westward. There is some confusion in the bedding of the coal in this drift, and some evidence of a shallow narrow basin producing a divergence of the gangways. The main N. gangway only on the regular S. dip is now mined.

These mines yielded, in 1856, 16,581 tons; in 1857, 18,943 tons.

A fourth of a mile E. of Mason's Tunnel, on East Norwegian, C. Frantz & Co. are mining the Orchard and Primrose seams above water-level on the Ellmaker Tract. The Orchard Bed dips Southward 10° or 12° at the drift-entrance; but on the breasts, 55 yards above the gangway, 200 yards in, the coal saddles over into a shallow basin on the N. The gangway, which is driven Westward, is 250 yards long. The Orchard Seam in this mine is 4½ or 5 feet thick, including 2 or 3 inches of slate, 2 feet from the bottom. The lower bench of coal is rough in texture.

The Primrose Bed, 7 feet thick, divided by 7 inches of slate, and 5 inches of bony coal, is wrought from a drift in which the coal dips 8° or 10° Southward. The gangway is mined 100 yards Westward.

C. Frantz & Co. mined, in 1857, 4123 tons of coal.

A colliery has been recently established in a shallow basin of the Orchard Coal-seam occupying a high position in the hill W. of Wadesville. From the gangway both dips of the coal are mined. Lessee, James Thomas.

In 1857, the Primrose Seam South of the basin was wrought by Mr Thomas, and yielded 15,841 tons of coal.

WEST NORWEGIAN.

East Mount Laffee Slope (page 147 of text)—Turner & Gowan (formerly C. Miller).—This is sunk on the bottom slate of the Mammoth Bed; length, 195 yards; to first level, 135 yards; to water-level, 75 yards. Dip, 50° at top; 61° at bottom. The coal above water-level was wrought from the old Mount Laffee Tunnel. The upper-slope level is wrought 1200 yards E.: the lower, 600 yards E. Both gangways W. encountered rock-fault, or a gradual thinning-away of the coal, until it entirely disappeared 260 yards from the slope. The "7-feet Vein" overlying the Mammoth is wrought from gangways, communicating by short tunnels with the Mammoth gangways.

The subdivisions of the beds wrought from this slope are thus stated by Mr Gowan :—

	Feet.
Coal,	4
Bone Coal,	1
Coal,	6
Coal,	2

	Feet.	In.
Slate,	1	3
Sandstone,	2	6
Slate,	2	0

	Feet.	In.
Coal,	9	0
Bone Coal,	1	6
Coal,	6	6
Bone Coal and Slate,	2	0
Coal,	6	0

The first slope-level at the slope was on fire in 1857, and no coal was taken from the mine.

T. T. Jenkins & Co.'s Colliery (page 147 of text)—formerly Pugh & Co.—This mine is situated upon the S. dip of the first anticlinal traversing this part of the region S. of the Mine Hill (Axis E). A slope is sunk 100 yards upon the Primrose Bed of coal, at an angle of 15°, or 60 yards below water-level. A drift follows the same bed E. at water-level. Owing to the fact that the anticlinal at which this bed arches over droops towards the E., this gangway turns N., then W., upon the N. side of the axis. This curvature of the gangway occurs 1400 feet E. of the slope. The North-dipping coal was wrought years ago from a slope-mine, the breasts of which have been entered by the drift gangway. From the present slope the gangway has been worked E. half a mile, and has not yet experienced the effects of the declining saddle.

The average thickness of the Primrose Bed in this mine is 6 feet.

Yield, in 1856, 13,838 tons ; in 1857, 19,958 tons.

C. A. Harper's Slope, on the *Lower Orchard Coal-Bed*, is situated 250 feet W. of Brown's Old Shaft : length, 419 feet ; to first level, 314 feet. Dip at the top, 22°, decreasing to 7° at the bottom, where it approaches the basin of the bed. The level gangway E. on the first lift is turned S. by the rising of the basin : a rising gangway is worked obliquely across the basin to nearly vertical coal on the S. side of the synclinal.

The Orchard Seam retains the thickness and character usual to it through this part of the region.

Yield, in 1856, 13,419 tons ; in 1857, 15,481 tons.

A company is proposing to sink a vertical shaft somewhere near Mr Brown's house in the basin.

D. P. Brown's Oak-Hill Slopes, on the Primrose Seam, are situated upon the S. side of the second anticlinal S. of Mine Hill (Axis F West). The old slope descends, at an angle of 28°, for 300 feet, being 263 feet below water-level. At the bottom the E. gangway is 450 yards long. The W. gangway, 400 yards from the slope, sweeps N. round the saddle, which declines W. into nearly vertical North-dipping coal.

From the foot of the slope a tunnel is cut 232 feet S. to the Lower Orchard Coal, dipping 35° S. Upon this bed a gangway is driven 300 yards W. and 750 yards E.

The new slope is sunk on the Primrose Coal 35 feet W. of the old one ; its length is 630 feet ; dip of coal at the bottom, 45° S. At this level the E. gangway is 200 yards long ; the W., 100 yards.

The usual subdivisions of the Primrose Bed, at the mines on West Norwegian, may be represented as follows :—

Coal, from 3 to 4 feet, Pink Ash ; Bony Coal, 1 to 3 inches, White Ash ; Coal, from 1 to 6 inches, Red Ash.

The Lower Orchard Seam is 5 feet thick, divided into two main benches, without parting-slates.

The West Oak-Hill Slope (Lessees, D. P. Brown & Co.) is sunk on the Primrose Bed from the outcrop on the first anticlinal S. of Mine Hill, between the valley of West Norwegian and the West Branch : length, 300 feet to the gangway level ; dip, S. 30° at the top, 12° at the bottom. Gangways are opened 100 yards E. and W. from the slope. On the W. side the dip becomes so gentle that cars are run up the breasts. The bed at this mine is reported to contain 8 feet of fuel.

Yield of the Oak-Hill Collieries in 1857, 30,860 tons.

West Delaware Mine (Rogers & Luther).—A slope is sunk on the Diamond Coal-bed, dipping S. into the fourth main synclinal basin S. of Mine Hill : length to lower level, 300 feet ; to upper level, 180 feet. Upon each level, gangways are driven E. and W. The upper level, W. 400 yards, ran into a rock-fault. A leader of the coal was followed 200 yards without passing through the fault. This fault or nip of the coal bears S.W. ; the lower level, 300 yards W., has not yet reached it. From the upper-level gangway, 400 yards E. of the slope, a tunnel is cut S. 70 feet to the vertical N. dip of the basin of the coal. This cross-cut passed through coal, and the bottom-slate of the bed, which is upheaved upon a sharp narrow anticlinal flexure, which divides the general basin into two compressed basins. A rising gangway driven E. from the S. end of the cross-cut, passed over the saddle into the N. small basin, meeting the gangway prolonged E. upon the regular S. dip, 300 feet E. of the cross-cut. In the N. basin the coal is bent sharply back upon itself, and seems to end downwards as a wedge-like mass: as this wedge expanded with the rise of the basin E., a large mass of coal was laid open to mining. W. from the cross-cut a gangway is opened 750 feet on the vertical coal. At the point where this gangway ends, the basin between the gangways is 233 feet wide. The outcrops at the slope are about 130 yards asunder.

The Diamond Seam is stated to average 9 feet in thickness in the parts of the mine now wrought. A band of slate, from 6 to 18 inches thick, not always present, divides the bed into two benches. Ash, deep red.

Yield in 1856, 43,072 tons.

The Old Peach Mountain Delaware Mines are abandoned.

Duncan Colliery (Lessee, J. F. Voorhies).—This slope, in sinking, follows a leader of the Lewis Coal-seam, which is from 3 to 7 inches thick. The inclination of the slope is 36° S. for 104 yards from the surface. It then passes 41 yards through a large body of sound coal, the full development of which has not yet been ascertained, to the normal bedding of the seam dipping 28°, which is followed 175 yards to the gangway-level. Total length, 320 yards, or 960 feet. The gangway E. from the slope communicates with the gangway driven W. from the slope on the Lewis bed, sunk at the bottom of the Old Shaft on the Centre Tract. This shaft is 255 feet deep to the Lewis Coal, upon which the slope is 510 feet long. The position of the Duncan Slope was established by an air-way driven to the surface from the gangway 800 yards W. of the Lewis Slope. Previous to this demonstration of the position of the bed on the Duncan Tract, every attempt to find it had failed. It would appear that the great expansion of the bed to which we have referred, is due to a sudden compression arising from the forced approach of the over and underlying slates as they near the outcrop. The line of this compression or fault rises Westward, as has been proved by an air-way W. of the slope, in which it was encountered at a higher level. The W. gangway from the slope is opened 700 yards; but no coal has been mined from it for the market.

The Lewis Seam is divided into three benches: beneath the top bench 4 inches of slate usually accompany the bed. The estimated average thickness of coal is stated to be 6 feet 6 inches. Ash, deep red, fracture semi-conchoidal.

The Lewis Shaft Colliery, worked by Mr Voorhies as agent, yielded, in 1857, 8554 tons. In 1858 it was not worked.

The Old Black-Mine Slope (wrought for many years by Mr G. H. Potts), on the York Farm, near Pottsville, was abandoned in 1857. It is nearly a fourth of a mile long, and has five levels of gangway communicating with it.

WEST BRANCH.

West Mount Laffee Slope (Turner & Gowan).—Situated on the S.E. side of West Branch Gap of Mine Hill. Sunk on the Mammoth Seam 62 yards below water-level; dip 50° at the top, 35° at the bottom. The average thicknesses of the Mammoth and Seven-feet Coals somewhat exceed that of the same beds wrought in the East Mount Laffee Slope. In the gangway the upper bed is confused and very variable, owing to irregularities in the top and bottom slates, which sometimes recede from one another, enclosing an immense body of coal. Above the gangway-level these irregularities become less frequent, and the coal is more uniform and sound. W. of the slope 50 yards this bed is entirely cut out by the approach of the top and bottom slates. The W. gangway on the Mammoth Coal is driven 78 yards; the dip grows less in that direction, causing a slight deflection in the gangway. The E. gangway on the Mammoth is wrought 800 yards to a dirt-fault, accompanied by a great diminution in thickness. The interval of 600 yards between the face of this gangway and the W. gangways from the East Slope, though suspected to be faulty ground, yet remains to be tested.

East of the slope 200 yards a tunnel is driven 46 yards S., from the top of the "Seven-feet Coal" through confused measures, which have hitherto been little understood. Careful examination of this tunnel led to the conviction, that for the first 17 yards it is cut through a shallow basin of the strata immediately overlying the Seven-feet Seam. That bed, rising to the tunnel-level, forms three narrow confused anticlinal rolls, and finally descends below the tunnel-level on a S. dip of 30°. The N. dip of the last and most important of these rolls is nearly vertical. A short distance W. of the tunnel an attempt was made to cut an air-way to the surface on the breast of the S. dip of this saddle; but 20 yards on the breast the coal turned over into a N. dip, and the attempt failed. The drooping of this saddle Eastward caused the abandonment of the gangway in that direction. The flexures we have described do not appear to be developed as important rolls in the strata to any great distance, though we may find in them an explanation of the fact, that the strike of the Mammoth at the West Mount Laffee Slope-coal ranges some distance N. of the same bed wrought by Doherty at the Dundas Colliery, No. 1, on the W. side of the valley.

It is probable that, in the prolongation of the West Mount Laffee Slope to a lower level on the Mammoth Seam, a flattening of the dip, or a synclinal in prolongation of the basin of the tunnel, will be encountered, and affect the breast in the coals.

This colliery, wrought four months in 1857, yielded 9382 tons of coal.

Dundas Colliery, No. 1 (page 168 of text)—Lessee, John Doherty (formerly C. M. Hill).—On S. slope of Mine Hill, at West-Branch Gap, W. side, the slope descends on the bottom slate of the Mammoth North Coal-seam, at an angle of 25° S. Length of slope, 773 feet; to first level below water-line, 485 feet. The upper level from the slope, and an old water-level gangway, encountered a rock-fault or nip of the seam 3100 feet W., and were abandoned. The lower-slope level is driven 1200 feet W.

Dundas Colliery, No. 2 (erroneously called No. 1 on page 168)—John Doherty (formerly Jones).—Situated 1000 feet W. of No. 1. Slope 849 feet long on the South-dipping Black Valley Seam; to first level, 545 feet: dip, 33° at the top, 22° at the bottom. The upper-slope level is mined 2100 feet E., and 3300 feet W. The lower level, 750 feet E., 850 feet W.

The following section represents the subdivisions of the coal-seams wrought at the two collieries:—

		Feet.	In.			Feet.	In.
Black Valley	Coal,	0	10	Mammoth	Coal,	2	6
	Bony Coal,	0	6		Slate and bone,	2	6
	Coal,	9	0		Coal,	1	6
	Slate, two thin coals, from 10 to	12	0		Slate,	...	4
Black Heath	Coal,	2	6		Coal,	4	0
	Slate and bone,	3	0				

The Black Heath and Mammoth seams range Eastward as one great bed, designated the Mammoth; whereas the Black Valley is known as the Seven-feet Coal. Towards the W., however, they appear as three entirely distinct seams, separated by many feet of conglomerate and sandstone. Thus, at the No. 1 Slope the Black Valley and Black Heath seams are separated by 15 feet of slate; but from that point Westward intercalated sandstone and conglomerate appear, which, at the water-level on Wolf Creek, actually exceed 125 feet in thickness, requiring nearly 200 feet of tunnel across the dip to pass from the one to the other. Even at the No. 2 slope, across which our section is measured, the seams are thrown asunder. In like manner the Black Heath is separated from the Mammoth in the same distance by 40 feet of conglomerate, requiring 63 feet of tunnel between the two. These facts make the hypothesis of the identity of the Black Heath and Seven-feet bed (see page 223) altogether improbable.

Dundas Colliery, No. 3 (Lessee, Morgan Brace).—This is a drift-mine at water-level working Westward on the (so-called) Reese Davis or Bast White-Ash Seam. The coal at the mine-mouth dips S. 35°; but 300 yards Westward in the gangway it basins, and rises a short distance, after which the gangway follows the S. dip. The average thickness of the seam is stated at 6 feet. The mine is now abandoned, temporarily at least. In 1857, 2789 tons were extracted from it.

Dundas Colliery, No. 4 (Lessees, Treck & Spencer).—The Kear Vein or Oak-Hill Seam is wrought at this colliery by a slope 480 feet long; an upper-level gangway leaves the slope 180 feet below the water-line. The coal at the slope dips S. 22° at the top, and 15° at the bottom. The upper level is mined 800 yards W.; the lower, 175 yards W. and 180 yards E. The lower gangway, 100 yards W. of the slope, encountered a dirt-fault 8 yards wide on the breast, but ranging nearly parallel with the gangway for 40 yards. In the upper level the same fault was struck 450 yards from the slope. It is there 15 yards wide through 70 yards of gangway length.

In the E. lower level, 140 yards from the slope, a large oval mass of sandstone occurs, lying within the coal, which, beneath the rock, is compressed to 2 feet of thickness. The coal has been cut away from its sides; but whether it is isolated from the natural top-slate of the bed by coaly matter is not proved. The coal in the vicinity of this curious feature is confused, soft, and sulphury. The subdivisions of the bed in this mine are thus stated:—

Coal, 4 or 5 feet; Coal, 1 foot 6 inches; Slate, 6 inches; Coal (14 inches bony), 3 feet; Coal, sometimes dirt, 1 foot 6 inches.

The character of the bed, and the extension of mining Eastward from West Branch, seem now to favour the view commonly entertained, that the Kear of Wolf Creek and Primrose of West Norwegian are identical beds.

Dundas Colliery, No. 5 (Holman & Co.)—A slope is sunk on the Diamond Seam 360 feet: dip at the top, 43°; midway, 25°; at the bottom, 45°. From the foot of the slope a tunnel is driven 25 yards S. to a seam of coal 2 feet 6 inches thick, upon which gangways are being opened. The Diamond Seam is 4½ or 5 feet thick in two benches, separated by 4 inches of slate. Gangways are worked 500 yards E. and W. From the gangway, 200 feet W. of the slope, a tunnel is driven 367 feet N. to a coal from 3 to 4 feet thick. This seam arches over a saddle beneath the surface, to form a shallow basin rising Westward. An air-way 80 yards W. of the tunnel proved the existence of the saddle.

This colliery yielded, in 1857, 17,429 tons.

Peach Orchard Colliery (page 169 of text)—Bullock & Spencer.—A slope is sunk on the E. side of the Valley of West Branch, immediately E. of the Old Wagner Tunnel, upon the Peach Mountain Seam, or the second coal-cut in that tunnel: length of slope 120 yards; dip, 30° S. From the foot of the slope a tunnel is driven N. and S. The first seam was cut 28 yards N. of the Slope Coal; it is 3 feet thick, and corresponds to No. 1 of the Wagner Tunnel. From this the tunnel is prolonged 45 yards N. to a seam of rough coal from 5 to 7 feet thick, dipping 30° S. Upon it a gangway is driven 200 yards E. In the opposite direction from the slope, the tunnel is driven S. to the Peach Mountain Seam, dipping 50° N., and is prolonged to the seams cut in the N. tunnel. Though the tunnel is driven 70 yards S. of the lowermost of these, no other seams are found, though the dip is still N.

Occupying the synclinal (o O) of the Peach Mountain, but basining 42 yards above the tunnel-level, there is a seam of coal, generally confused, though sometimes yielding 8 feet of coal. A slope 100 yards long descends upon this bed to the basin, on both sides of which breasts are wrought in the coal. The rise of the basin E. throws out the upper seam, and after it the Peach Mountain. In its E. extension this latter bed was wrought many years ago by John Reed for the Delaware Coal Company. Following W. from West Norwegian the S. dip of the coal on the anticlinal next S. of the basin, he tunneled through into the basin, and extracted the coal.

The Peach Mountain Seam is denuded away from the flat ground of the West Branch, but descends in a steep N. dip on the opposite side of the valley. A small colliery was established on the bed at this point, from which Mr Bright, in 1857, shipped 4423 tons.

The Peach Orchard Colliery is temporarily abandoned.

MINERSVILLE.

Lewis Colliery (page 169 of text)—Lessee, William De Haven.—Situated at the W. end of Minersville. The slope descends on the Phœnix Bed, dipping 40° S. from the anticlinal of the Old Minersville Tunnel; length, 123 yards. From the slope a tunnel is driven S. 70 yards to coal from 3 to 4 feet thick, and is prolonged 100 yards to the Peach Mountain Seam, dipping 45° S. Gangways are driven from E. to W. upon all these beds. The Phœnix Bed, though about 5 feet thick, is slaty and impure; it is not now wrought. The Peach Mountain Seam is thus subdivided:—

Coal, 3 feet; Coal, 2 feet to 2 feet 6 inches; Slate or dirt, 2 inches; Coal, 2 feet.

A third of a mile W. of the Minersville Slope the Peach Mountain Coal is mined from a slope 90 yards long, It dips 40° S. The gangway is driven 400 or 500 yards W. from this slope. A gentle roll of the coal 200 yards W. displaces it in the gangway ; a short tunnel is driven to the bed, which dips so feebly S. as to admit the cars on the breast. The coal is shelly in the neighbourhood of the disturbance in the mine.

WOLF CREEK.

William Penn Colliery (page 169 of text)—Agent, J. C. Harper.—The Kear or Oak-Hill Seam on the E. side of the valley of Wolf Creek forms a shallow basin rising E., from which the coal has been extracted by Holman & Co. South of this basin it arches the anticlinal F West, beneath a stratum of coarse conglomeritic sandstone. Harper's Slope cuts 20 yards through this rock to the coal, which is struck near the saddle, and is followed on the S. dip : length of slope, 480 feet ; dip, 40° at top, 45° at bottom. There are two levels 213 feet apart on the slope. The E. gangways have been mined nearly 600 yards. The upper level W. is 100 yards long ; the lower, 400 yards.

The seam is estimated to contain 10 feet thickness of coal at this colliery ; it sometimes exceeds this.

The yield, in 1857, was 12,545 tons.

Schollenberger Colliery (page 171 of text)—Lessee, B. Bartholomew, jun.—Situated on the S. side of Mine Hill, Wolf Creek. The slope descends S. on the bottom slate of the Black Valley Coal, 340 feet to the first level, and 286 feet farther to the lower level. The inclination is 34° at the top, increasing to 44° at the first level, and 37° at the bottom. At the foot of the slope the coal is found greatly confused and worthless. A tunnel cut S. through this "trouble" 155 feet to the next higher coal, displays an obscure faulty synclinal and anticlinal structure in the Slope Coal and its associated rocks. The Bast White-Ash Coal, or Reese Davis Seam, laid open to mining by this tunnel, is subdivided as follows :—

Coal, 1 foot ; Bone Coal, 6 inches ; Coal, 3 feet 6 inches ; Coal, rough, 4 feet.

The E. gangway 900 feet from the tunnel curves S. upon West-dipping coal. After rounding the point of the basin, it returns to its former course upon the N. dip. to meet the gangway driven W., which encountered the uprising of the same basin in that direction 300 feet from the tunnel. At this point the coal is somewhat confused. The coal at the E. end of this basin dips 23° W. ; the N. dip varies from 19° to 23°. An anticlinal axis (F West) ranges within 100 feet S. of the gangway on the S. side of the basin. Near the foot of the slope a tunnel is cut N. from the Black Valley Bed 156 feet to the Black Heath Seam, dipping S. parallel to the former. Midway in the tunnel a small seam of soft coal was passed. The several members of the Black Heath are,—

Coal, rough, 1 foot 6 inches ; Coal, 10 inches ; Coal, 4 feet ; Coal and Slate, 1 foot.

Gangways are worked more than a fourth of a mile E. and W. of the tunnel.

The Black Valley Seam proved so unprofitable that the upper-level gangways upon it were abandoned.

Schollenberger's (Old) Slope—(formerly Heilner's).—This slope is 400 feet S.E. of the former. It is 100 yards long below water-level on the Bast White-Ash Coal seam at an angle of 30° S. At the foot of the slope a tunnel cut S. 130 feet intersects two small seams of poor coal. From the gangway 300 feet W. of the slope a tunnel is driven N. 350 feet to the Black Heath Coal, cutting the Black Valley Bed midway. The Black Heath Bed has been mined a mile W. by gangway from the tunnel. W. of the tunnel 3200 feet the strata below it are cut through by a tunnel 60 feet long to the "Back Vein" coal-bed, which is thus subdivided,—

Slate and Coal ; Rough Coal, 6 inches ; Slate, 4 inches ; Coal, 2 feet 10 inches ; Coal, 2 feet 5 inches ; Coal and Slate, 2 feet to 2 feet 8 inches.

A gangway is driven several hundred yards W. of the tunnel upon this bed.

The Schollenberger Collieries, in 1857, produced 40,513 tons of coal.

Sutton and Wright's Tunnel—(Lessees, Cain, Hacker, & Cook).—This tunnel is cut at water-level through South-dipping strata 260 feet N. to a seam of coal overlying the Black Heath Seam, called the "Red Ash." This is followed by gangways 1560 feet W., and a tunnel is cut 60 feet to the Black Heath Bed. The Back Vein, also tunneled to, is worked W. to the line. Following this Black Heath coal 1030 feet W., a tunnel is driven from the gangway S. across the measures through a confusion of dips 280 feet to a small coal, which was traced 200 feet

S.W., and the tunnel resumes its direction 80 feet to the Susan, and 110 feet farther to the overlying Petherick coal-seams. The Susan Bed is 7½ feet thick, as follows :—

Rough Coal, 8 inches; Slate, 4 inches; Rough Coal, 2 feet; Slate, 3 inches; Coal, 1 foot 3 inches; Coal, 3 feet.

It has been mined 300 yards W. from the tunnel. The Petherick is thus subdivided :—

Coal, 2 feet 2 inches; Coal, 4 feet 7 inches; Slate and Coal, 1 foot.

It dips 41° S. at the tunnel, but followed E. the gangway deflects S. round a small basin, and into a N. dip. of 14°, following which W. it will perhaps meet within 100 yards the air-way from the Bast White-Ash Slope Colliery previously described. Driven W. from the tunnel, the gangway workings connect with the E. workings on the same seam, known as the Forestville Bed, mined from West-West Branch.

It is an opinion commonly entertained that the Petherick and Susan beds cut in Bast's Tunnel, and wrought at a higher level at the S. end of Sutton and Wright's Tunnel, are the same as the Black Heath and Back coal-seams wrought far below water-level in Schollenberger's gangways, and at water-level at the N. end of Sutton and Wright's Tunnel; also, at a still higher level, from Serrill's Upper Tunnel. In explanation of this hypothesis, a sudden and sharp anticlinal inversion of the strata is supposed to occur, causing the Petherick and underlying bed to descend so far below water-level as to rise on the natural S. dip in Schollenberger's gangway. We know of no facts to justify this view of the case. The anticlinal (F West) which droops E., affecting Bast's E. gangway on the Reese Davis Bed, as described, in its prolongation W. ranges through the confused ground of Sutton and Wright's Inner Tunnel. We also know that the basin next N. of this rises rapidly W.—so rapidly that it expires without affecting the Schollenberger gangway on the Black Heath Seam. Inasmuch as the identity of the Reese Davis Coal at Schollenberger's and Bast's White Ash is proved by mining, the more natural view of the Petherick and Susan seams is to regard them as represented at Schollenberger's by the Black Valley, and a soft seam of dirt and coal, which in that mine is not worth working.

Yield of this colliery, in 1857, 19,843 tons.

Borda's Black Heath Colliery, head of Wolf Creek (page 171 of text)—Forest Imperial Company's Lands.—The tunnel by which the seams wrought at this mine are entered, known as Serrill's Upper Tunnel, is situated 175 yards E. of Sutton and Wright's Inner Tunnel, and 160 feet above it. As shown in the engraved section, it is driven N. into Mine Hill, cutting three notable seams of coal. The first of these, or the Black Valley Bed, is so confused at the tunnel that it was not mined there, but was tunneled to from a gangway driven 400 feet W. on the first bed. From this tunnel the Black Valley Seam was wrought W. nearly 400 yards. The breasts on the Petherick Seam, wrought from the W. gangway of Sutton and Wright's Inner Tunnel, communicate with this old gangway, thereby establishing the identity of the bed under two names.

The mining from the main tunnel on the Black Heath and Back seams has been very extensive. The breast on the Black Heath Coal from the tunnel W. admits a counter-level above the main gangway for 1150 yards, from which point the subsidence of the dip and the rise of the surface W. allow of two counter-gangways. The coal in the main lower gangway is finally cut out by rock-fault, which caused a stoppage of the gangway 1800 yards W. of the entering tunnel. The dip of the coal in the neighbourhood of this fault furnishes some indication of a basin rising W., accompanied by a small anticlinal roll on the S. The gangway working W. from a slope, sunk 70 yards on the coal below this main-tunnel gangway, encountered a change of dip and a rock-fault or "nip" of the coal, 2000 feet E. of the rock-fault above mentioned.

No difficulty, similar to that in the lower levels, has been met with in the counter-gangways. The slope level worked E. connects with the gangway on the Black Heath Bed, driven W. of Sutton and Wright's Inner Tunnel.

At several points tunnels have been driven N. to the Back Vein, which is worked from the entering tunnel parallel to the Black Heath, and in a similar manner. The total length of the gangways upon the Black Heath and Back seams which have an outlet at the Serrill Upper Tunnel exceeds 6 miles.

This colliery shipped in 1857, as the result of four months' mining, 30,754 tons. Estimated capacity for 1858, 80,000 tons.

Bast's White-Ash Colliery (page 171 of text)—Lessee, George H. Potts.—The Old Slope descends S. 195

feet upon the bottom-slate of a small seam, overlying the Bast White-Ash or Reese Davis Coal-bed; it then cuts through the underlying strata to the latter bed. Length, 402 feet.

The dip decreases uniformly from 46° to 18°.

The thickness of the coal averages from 7 to 8 feet, as follows:—

Coal, 1 foot; Soft Coal, 3 inches; Coal, 3 feet 6 inches; Coal, 6 inches; Coal, 3 feet 3 inches; Coal and Slate, 0.

An anticlinal flexure (F West), drooping E., shortens the breasts, and causes the gangway to deflect N. a fourth of a mile E. of the slope. The synclinal basin which, by rising W., turns the gangway, in confused coal on the lower level from Schollenberger's Slope Tunnel, affects this gangway similarly, causing a reverse curve. From this gangway, 300 feet E. of the slope, a tunnel is driven S. 175 feet to a seam which is mined a short distance E. and W.

From the gangway, 530 feet W. of the slope, a tunnel is cut S. 105 feet to the seam upon which the upper portion of the slope descends. This bed is 6 feet thick, and is mined 1600 feet W. In the opposite direction a tunnel is driven 386 feet to the Susan Vein, cutting the Petherick Bed 66 feet S. of the latter. The Petherick only is extensively mined by gangways from this tunnel. It has been followed 3400 feet W. and 1000 feet E. In an air-way ascending the breast of the coal at 1440 feet W. of the tunnel, the dip changes, 332 feet above the gangway, to N. 37°, and in 34 feet, to a basin of which the S. dip averages 6° for 105 feet, when another turn occurs, over which the coal was not followed; but the bed reappears on a S. dip in the gangway from Cain, Hacker, & Cook's Tunnel. The narrow basin thus formed rises E., and the gangway from the tunnel has already passed round it, and is expected to communicate with the air-way. The two small anticlinal rolls we have indicated droop E., causing confusion in the coal, and a shortening of the breasts in the Black Heath Coal-bed 1000 feet E. of the air-way.

The New Slope is sunk upon the same Bast White-Ash Seam 650 feet W. of the former. It is 498 feet long to the Old Slope gangway, and 853 to the bottom. Inclination 49° at the top, 27° midway, and 33° at the bottom.

The gangways running E. are 1200 feet long, and those W. 700 feet. From the foot of the slope a tunnel is cut 70 feet S. to the upper coal-bed, upon which gangways are opened for mining.

Bast's Red-Ash Colliery (Lessee, George H. Potts).—The slope is sunk on the Diamond Coal-seam dipping S. 40°; length, 664 feet. The upper level is worked out and abandoned. The E. lower gangway, 2000 feet long, nearly approaches Holman's Workings, coming W. from West Branch. The W. gangway is 3800 feet long. From the W. gangway, 275 feet from the foot of the slope, a tunnel is driven 400 feet S. to the Cockle Bed, 5 feet thick, dipping 40° S. Upon this coal gangways are worked 400 feet E. and W. Midway in the tunnel a 3-feet bed of impure coal was cut, and followed 400 feet W.

The Diamond Seam comprises three benches of coal, the lower and middle separated by 4 inches of slate. The entire thickness of the bed ranges from 6 to 7 feet.

The yield of the Bast Collieries, in 1857, was 106,773 tons.

Kear's Colliery (page 172 of text).—Slope descends 187 yards on the Kear or Oak-Hill Seam: dip 30°, increasing to 38°; length to upper level, 87 yards. The upper level is worked 200 yards E., and both levels 1600 yards W. In the upper level, 1430 yards W. of the slope, a small synclinal and anticlinal roll of the coal causes a sigmoid curve in the gangway, throwing it 125 feet S. of its previous line. The lower level is affected in precisely the same way by these flexures, 1050 yards from the slope. Intermediately, a counter-gangway is similarly curved.

The Kear Bed is stated to average 10 feet thickness, including from 8 to 9 feet of coal.

WEST-WEST BRANCH.

Forestville Colliery (D. Glover), Forest Improvement Company's Lands, S.E. Side of Mine-Hill Gap of the West-West Branch.—Slope sunk 137 yards on the bottom-slate of the Forestville or Black Valley Seam; dip 22° S. at top, 30° at bottom. From the foot of the slope, gangways are driven 1200 yards E. and 1400 yards W.

The dip of the coal diminishes going E., and increases W. to 50°. In the W. gangway the coal is faulty and impure for two-thirds of the distance mined.

Above water-level the coal has been wrought from three levels of gangway.

The subdivisions of the coal are as follows:—

Davis Coal, 4 feet 6 inches; Slate and Bone, 4 feet; Coal, 2 feet; Bone Coal, 3 inches; Coal, 3 feet; Slate, 6 inches; Coal, 3 feet 6 inches.

The above section represents the bed under favourable conditions. In parts of the mine the Davis Bed only is important; in others it is not wrought, and the main coal depreciates in thickness and quality.

Yield, in 1857, 56,995 tons. Capacity for 1858, estimated at 50,000 tons.

Franklin Colliery, S.W. Side of Mine-Hill Gap of the West-West Branch (William De Haven).—Slope sunk 100 yards on the Kear Seam; dip, S. 34° at top, 55° at bottom. Gangway driven E. 1300 yards, the dip augmenting to 70°, gangway W. 1100 yards. Average length of breasts on W. side, 95 yards to water-level; on E. side, owing to steep dip, 40 yards. The prevailing subdivisions of the bed are as follows:—

Coal, 3 feet 6 inches; Coal, sometimes 1 foot of it bony, 2 feet 6 inches; Coal, 2 feet 6 inches to 3 feet—Ash, pinkish grey.

Shipments in 1857, including coal sent from the Lewis Colliery, near Minersville, 53,701 tons.

Dolbin and Rogers' Colliery (at Woodside).—Slope sunk on bottom-slate of the Reese Davis or Bast White-Ash Coal-seam, dipping S. 28° at top and 35° at bottom; length, 108 yards. At the bottom of the slope the coal was squeezed out by a rock-fault. After driving 200 yards E. through rock, the coal reappeared as a workable bed, and is mined for 700 yards E. of the slope. From the slope a tunnel is driven S. 32 yards to a small seam, upon which a gangway is opened W. for 257 yards, where a tunnel is cut back to the slope-coal, here only 3 feet thick. A gangway follows it W. a short distance.

At water-level a tunnel is driven towards the slope 420 feet to the Reese Davis Coal, which was worked out years ago. W. of the tunnel 1700 feet, a second tunnel is cut N. 90 yards to the Black Valley or Forestville Coal-seam. Midway in the tunnel a small seam was passed. The gangway on the Forestville Seam is worked nearly a mile E. The average thickness of the coal is about 6 feet.

The yield of this colliery, in 1857, was 35,333 tons.

Big Diamond Slope (Charles Miller's).—The Big Diamond Seam which, owing the influence of the drooping anticlinal (M), arches below water-level on the E. side of the valley of West-West Branch, rises with the anticlinal W., and on the W. side of the valley a slope is sunk upon it to a depth of 140 yards below water-level. The dip at the top is 34° N., but it declines to a small basin, and rises on the opposite dip of a small anticlinal roll which was overcome by a cross-cut of 15 yards. From the foot of the slope a gangway is driven along the basin 200 yards W. At this point the basin seems to be flattening out; a cross-cut is made Northward 24 yards to the regular N. dip of the coal, upon which the gangway is driven 1200 yards W. In the opposite direction from the cross-cut the gangway is driven towards the slope, and 30 yards E. of it. The E. gangway from the foot of the slope is abandoned, because the coal is squeezed and thin. The Diamond Seam is stated to yield on an average a thickness of 6 feet 6 inches of coal.

Phœnix Colliery, E. Side West-West Branch (page 174 of text)—C. Miller.—Slope sunk 100 yards below water-level on the Phœnix Seam, or Cockle's Red-Ash (erroneously designated in our section as the equivalent of the Oak-Hill Seam), flanking the S. side of the second anticlinal S. of the Diamond Slope, or axis N. The dip is S. 24°.

From the bottom of the slope a gangway runs 800 yards W. At the end of this gangway a change of dip occurs, from a S. dip of 20° into a N. dip of 60°, becoming vertical in the breasts. The coal is confused.

From the slope Eastward a gangway is driven 1000 yards; a tunnel is then cut Northward through the anticlinal of the coal, from 35° S. to a 45° N. dip of the bed. This anticlinal droops gradually Eastward. From the N. end of tunnel the gangway is driven W. 370 yards to the rising basin of the coal, which swings the gangway N. to the regular gentle S. dip of the coal on the flank of the anticlinal next N. This anticlinal (M), which causes the arch of the Big Diamond Coal to droop below water-level in ranging from the

W. to the E. side of West-West Branch, as it subsides Eastward will in like manner affect the Phœnix Seam. The gangway driven 400 yards E. of the turn at the basin is already deflecting Northward as the coal changes from S. to E. dips.

The old water-level gangway was affected in a smilar manner.

The average thickness of the Phœnix Seam is 4 feet 6 inches of coal. On the first S. dip the coal is shelly, but in the basin it is sound.

The Old S. Phœnix Slope is sunk 50 yards on a seam from 3 to 4 feet thick, but so impure that but little coal was taken from it, and the mine has been abandoned.

Shipments in 1857, including Big Diamond Colliery, 38,889 tons.

Beury's Colliery (formerly Macdonald's), two-thirds of a mile E. of the Phœnix Colliery.—The Kantnor or Peach Mountain Coal-seam, dipping S., is entered at water-level by a drift which follows it Eastward 450 yards. At this point the gangway turns Northward, while the coal, warping round the drooping anticlinal (**N**) of the Phœnix Mine, is completely crushed out. From the gangway near the drift-mouth a tunnel is cut N. 107 feet to a smaller underlying coal, thought to be the seam of the S. Phœnix Slope. This bed is faulty and impure at the tunnel. The measures separating it from the Peach Mountain Coal are represented as having so far thinned away at the end of the main gangway that a short oblique tunnel penetrates to it. The coal at this tunnel is 5 feet thick, and sound. The bed is mined 150 yards on the N. side of the anticlinal. Shipments in 1857, 3644 tons.

Thomas Cassiday's Colliery.—On the W. side of the West-West Branch, a little below the Phœnix Colliery, a drift enters upon a seam of coal 3 feet 6 inches or 4 feet in thickness ; dip 23° S. The gangway is driven 500 yards W. Owing to the gentle dip of the bed, and the height of the upland above the water-level, the breasts are 100 yards long. The Peach Mountain Coal is opened on the same dip, a short distance S. of the drift, but it is not mined. Shipments in 1857, 8356 tons.

At Cressonville, between the West Branch and the West-West Branch, the Salem Coal has long been wrought by a slope on a S. dip. The length of this slope is about 500 feet to the lower level. Above this there are two others not now worked. The upper level E. was driven to a fault ; the second level E. is 150 yards long, coal unsound ; it is driven half a mile W. The lower level is driven 200 yards E. and 500 W. Shipments in 1857, 2608 tons.

N. of this slope the Rabbit Hole and Faust seams have been wrought above water-level, and the tunnel and Black Mine by slopes below. These works are now abandoned.

Fogarty's Slope Colliery, on the Black-Mine Coal near the W. Branch, is now abandoned.

In the *Sharp Mountain*, at the gap of the *West Branch*, a seam of coal, the third ascending in the series, is wrought to some extent by John Doherty. The seam dips S. 80°. Two gangways at different levels are driven Eastward from the gap : the upper is 300 yards long ; the lower, 400 yards. The thickness of the coal in the lower level is 13 feet ; in the upper the average is about 10 feet. It is divided by a slate band 4 or 5 inches thick. The upper member is variable ; the lower is solid, and in the lower gangway of increased thickness. It is confidently asserted by some persons that the quality and appearance of this coal are so nearly like the Mammoth of Mine Hill as to establish their identity. The test is not a sound one. It seems to be the Barcleugh Seam of our section, given on Mr Bennett's authority.

Salem Colliery (page 175 of text)—B. Tyson & Co.—In the valley of the West Branch below Llewellyn.—A slope is sunk on the tunnel-seam 127 yards ; dip S. 40° at top, 45° at bottom. The gangway driven W. is 600 yards long. Ninety yards W. of the slope a tunnel is driven N. 88 yards to the Black-Mine Seam. A bed 15 inches thick was cut 33 yards N. of the slope coal. The Black Mine dips 38° at the tunnel, though flatter on the breast. The gangway is driven 150 yards E., and 500 yards W.

A new slope is now sinking upon the Black Mine at an angle of 30° at the top and 40° below. It intersects the gangway 15 yards E. of the tunnel. It will be 250 yards long from the outcrop, or 100 yards below the tunnel-level.

The tunnel-seam averages 5 feet thickness in this mine : it is not divided by slates, though somewhat tending to dirt-faults. The subdivisions of the Black-Mine Seam are thus stated :—

Coal, 1 foot 6 inches; hard dark argillaceous Sandstone, 10 inches; Coal, 2 feet; Dirt undermining, 2 inches; Coal, 2 feet 6 inches.

The rock-parting is sometimes wanting, and occasionally is replaced by slate.

Yield of this colliery, in 1856, 22,276 tons; in 1857, 23,988 tons.

The Old Salem Slope-Mine on West-West Branch is abandoned.

Miller's Colliery (S.E. of the Old York Tunnel, Costerville).—The Kear or Otto Grey-Ash Coal-seam, which is cut 40 yards S. of the N. end of the Old York Tunnel, dips Southward below water-level, and, after forming a basin, is elevated below the surface on the crest of a saddle (**M**). The slope at this colliery is so located as to strike the seam on the saddle, and descend with it on the S. dip. The slope was sunk 60 yards at an angle of 35° through North-dipping measures to the coal, which was followed 30 yards on an average dip of 40°, when it was nipped out, but came in again near the bottom of the slope. Total length, 130 yards. From the slope, gangways are opened 90 yards W. and 75 yards E. The Kear Bed at this mine is divided into two benches of coal, each 5 feet thick, separated by Bone coal from 5 inches to 2 feet in thickness. No coal shipped in 1857.

MUDDY BRANCH.

Morgan and Edwards' Tunnel Colliery (page 176 of text)—D. Edwards, Forest Improvement Company's Lands.—This tunnel (a section of which, so far as it had been driven in 1853, is presented on page 157 of the text) is driven N. into Mine Hill above water-level at the head of the valley of Muddy Branch. It intersects a number of seams of coal at the following distances from the mouth:—

160 feet of loose earth to the Brittain Seam, 10 feet thick; 261 feet to the Anderson Seam, 9 feet coal and slate; 563 feet to the Forestville or Black Valley Seam, 10 feet thick; 592 feet, passing a small seam, to the Billy Best Vein, 7 feet thick; 680 feet, passing two small seams, to a 3-feet bed of slaty coal at the end.

The dip is nearly uniform 65° S. The only seams wrought from this tunnel are the Forestville and Best. The gangway on the Forestville Seam is driven E. 330 yards, and 1040 yards W. On the Best Vein the gangway is worked 140 yards W. and 120 yards E. The extension N. of the tunnel from the Black Valley Seam was made in 1856–57. Yield in 1857, 10,477 tons, mining only a portion of the year.

Forest Improvement Company's Otto Mines (R. Heckscher & Co.)—At this colliery three seams are wrought—the Grey-Ash, sometimes called Brittain's, and represented to the E. by the Kear or Primrose Seam; the White-Ash or Forestville Black Valley Seam; and a small seam underlying the latter, and known as the Little Vein. The first is now wrought exclusively below water-level, the two last above water-level only.

The structural features developed by the mining upon these seams are among the most curious and instructive anywhere exhibited in the region. We shall attempt to describe these, so far as they are at present understood, by aid of the annexed diagram.

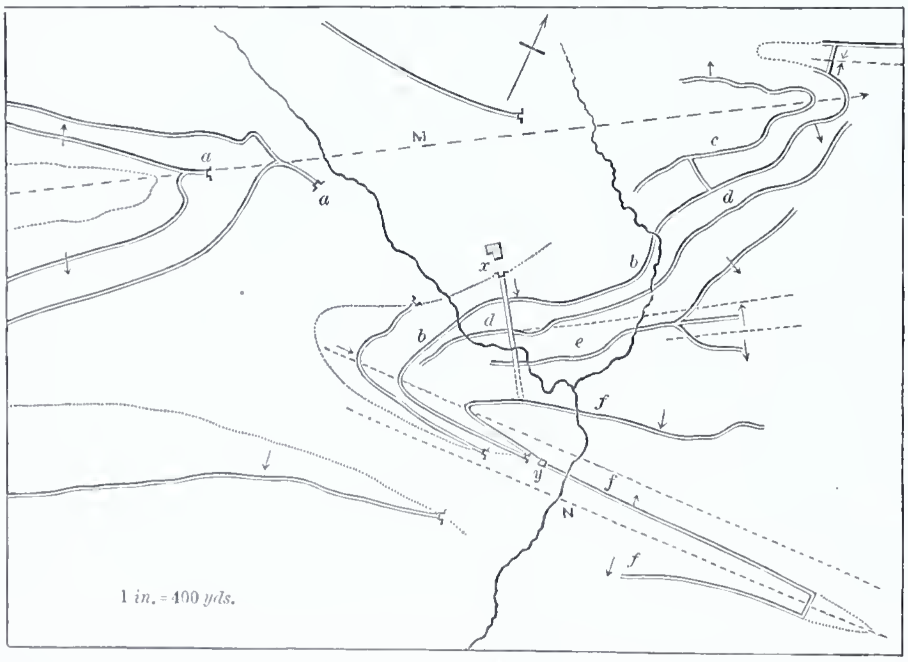


FIG. 312.—Ground Plan of the Otto White and Grey Ash Collieries.

The broad anticlinal (**M**), the axis of which ranges immediately S. of the Falls of the Swatara, is flanked on both sides by the Otto White-Ash Coal and its underlier, the "Little Vein." On the W. side of the Swatara the two outcrops of the same seam are not less than 900 yards apart; but the anticlinal droops E., causing the outcrops to converge and unite 2000 yards E. of the stream. At this point the coals dip E., and are entered at and above water-level (the upper, or White-Ash Seam, is near the anticlinal axis) by two short tunnels, from which gangways diverge more and more, going W. as they approach the Swatara. On the S. dip the gangways are driven a mile W., and on the N. 1600 yards. The average N. dip is 50°, the S. 25°. At convenient points, tunnels, the lengths of which vary with the angle of dip, are driven to the Little Vein, which is mined on both dips of the anticlinal. The actual thickness of rock cut through by these tunnels is about 40 feet. Gangways are driven on the Little Vein parallel to the main gangways, and the small seam is wrought in the same manner, though not to the same extent. The main coal averages a thickness of 10 feet when sound. The S. gangways are abandoned because the coal is entirely cut out by rock. The lower coal, 6 feet thick when regular, is liable to degenerate to slate.

The Otto Grey-Ash Seam is estimated to lie 100 yards higher in the series than the White-Ash Bed. The gangways upon it, both above and below the water-level, have, in keeping their level, been influenced by three well-marked anticlinal rolls, including as many synclinal basins.

The anticlinal of the Swatara Falls observes the normal direction common to all the great axes of the region, until it approaches the openings on the Otto White-Ash Seam above described. From these, as it expires E., it seems to be deflected 10° N. of its previous course, and causes a sharp curvature in the Grey-Ash Seam in the water-level gangway, and a counter-level under cover of high ground. From the water-level gangway on the N. dip of this axis, communication was made 870 yards from the York Tunnel, across a narrow basin rising W. with the old W. gangway on the same bed, dipping S. It appears, therefore, that we have at this point the W. extremity of the basin of the York Tunnel as affecting this bed. On the S. side of the anticlinal axis the gangway pursues a devious though general S.W. course for 750 yards to a slope, following the coal below water-level in the direction of dip S. 35° E., the angle of dip 20°. Leaving, for the present, the water-level gangway, and descending with the slope 60 yards, we find the dip diminished to 8°. Sixty yards still farther down the slope it again augments to 16°. At both these levels, gangways are driven E. upon the bed. The lower gangway, 180 yards E. of the slope, is deflected N. a short distance, and again resumes its course; but 300 yards from the slope the joint effect of a small anticlinal subsiding W., and a synclinal rising in the same direction, affords opportunity for three gangways to diverge—one turning S., to pursue the S. side of the anticlinal; one observing the N. side, the dip of which, amounting to 11°, is common also to the basin; and a third, driven N.E., following the gentle S.E. dip of a basin which is widely expanding and rising towards the W. This branch gangway is driven 350 yards; the two preceding, 100 yards each. The upper level of the slope is slightly affected by the prolonged rise of the basin (which also causes the gentle dip of 8° *in* the slope); but its general course is nearly parallel to the water-level gangway, and it has been worked 700 yards N.E., or nearly to the axis of the great anticlinal. It is impossible to estimate the full significance of the presence of this small anticlinal, which causes the branching of the gangways; whether it becomes important farther E. and represents axis (**M**) on West-West Branch, is a question the future must determine.

Westward from the slope the water-level gangway and the two slope-levels, as far as they have been driven, come under the influence of a synclinal basin, which, observing the normal direction, rises and expands so rapidly towards the W. that its effects are entirely lost on the flank of the axis of the Falls: nor is this all, for, as we will presently show, an anticlinal (**N**), the axis of which ranges parallel and about 100 yards S. of that of the basin while drooping E., rises and flattens out towards the W., so that we are nowhere able to discover its identity as a distinct flexure, unless we choose to regard that anticlinal ranging S. of Fisher's Basin as a Western extension of the same. The effect of the gradual obliteration of the N. dip, common to the saddle and the basin, is a great expanse of lower measures having a general S.E. dip. In the water-level gangway the rise of the basin is encountered 225 yards S.W. of the slope. From this point the gangway observes an E. course 275 yards to the entrance, from which, driving in a direction contrary to that we have been tracing, the strange developments we have been describing were made. A gangway at a higher level on the breast bends round the basin, and comes out at the surface on the opposite dip. At the drift-mouth of the water-level the dip of the coal is vertical N. Twenty yards E. of this a shaft is sunk 45 yards on the coal, and gangways are driven. W. of the shaft 150 yards, the rise of the basin is encountered at the gangway level. The coal is mined round on the S. dip 100 yards, until it meets the bottom of the slope prolonged 192 yards below the water-level gangway. E. of the slope the lower gangway is driven 450 yards on an average dip of 14° S. E. from the shaft a gangway is driven on the vertical dip 550 yards to a tunnel cut S. 100 feet across the axis to the coal on its S. side, dipping 45° S. From this tunnel a gangway is driven 350 yards W. At the face or far-end of this gangway it is 450 feet to the gangway on the N. dip. Above water-level on this S. dip the coal was wrought by drift many years ago.

The following section represents the subdivisions of the Otto Grey-Ash Seam, when fairly developed:—

Coal, 2 feet; Coal, 3 feet; Bony Coal, 2 feet; Coal, 2 feet; Dirt, 2 inches; Coal, 3 feet 6 inches.

It is comparatively free from fault, though the average thickness of marketable coal in the bed is hardly so great as we have stated.

The shipments from the Otto White-Ash Colliery in 1857 amounted to 49,778 tons; from the Otto Grey-Ash, 55,214 tons. The capacity of the two mines for 1858 is estimated at 130,000 tons.

Branchdale Colliery (page 176 of text)—Dewart Lands—Lessee, C. C. Boyer (formerly Macdonald).—The slope is sunk on the S. dip of a saddle (**P**) of the Spohn Coal-seam at an angle of 35°; length of slope, 350 feet. From the foot of the slope a gangway is driven 300 yards E. In the opposite direction the gangway pursues a W. course for 850 yards, where the coal is squeezed out. E. of the fault a slowly-rising gangway is opened obliquely up the breast 250 yards, and a level gangway is driven some distance W. until it swings round the point of the declining saddle. The rising gangway crosses this saddle, which dips 4° W., and is worked 400 yards E. on the N. dip until it is affected by a basin rising E., which causes the level to swing off to the N. The breasts from the gangways we have described communicate with the old counter-level gangway of Macdonald, which curved round the point of the saddle and the basin. The bed averages, when sound, from 4½ to 5 feet of coal.

An attempt was made to reach higher coals by a tunnel driven S. from the gangway 700 yards W. of the slope. This tunnel, 285 yards long, cut three small dirt-beds, but no coal of workable value.

SWATARA.

Swatara Colliery (page 178 of text)—Lessees, Brown & White—Forest Improvement Company's Lands.—The upper mines consist of two drifts entering at water-level on the N. side of the great anticlinal (**M**) of the Swatara Falls. The seams wrought correspond in relative position and character to those mined in Fisher's Basin, S. of the Falls axis. The N. drift follows the bottom slate of the upper coal of Fisher's Basin, or the "Red-Ash Vein"—so called because one of its benches yields a Red Ash—on the horizon of the Forestville Seam. The gangway pursues a W. course 400 yards, when it is deflected N.E. by the rising basin of the coal, in a uniform direction as far as wrought, or 400 yards on the S. dip. The N. dip at the mine-opening is 25°; it declines gradually to 8° at the end of the basin, and on the S. dip rises to 30°. The thickness of the seam is 10 feet.

The gangway in the lower bed on the N. dip of the basin ranges parallel to that in the upper, 35 yards distant. It is in like manner affected by the heading-up of the basin W., and sweeps round to the E. a fourth of a mile from the mine-mouth. The thickness of this seam, known as the "Little Vein," is from 5 to 6 feet.

It is worthy of remark that the gangways on the S. side of the basin lie precisely in the range of the gangways driven W. from Muddy Branch, on coals doubtless the same as those flanking the N. side of the Falls anticlinal.

Brown and White's lower mines are situated in the synclinal known as Fisher's Basin, lying S. of the Falls axis. The coals wrought are the same we have shown above; they are exhibited in the Swatara Section. On the lower seam two gangways are driven W. at different levels on the N. side of the basin—one on the S. dip, and one in the centre of the trough. As the basin sinks or deepens W., the latter gangway, preserving its level, branches 140 yards from the entrance, the branches following the coal on the opposing dips. The transverse ravine of Big Creek, 800 yards W. of the drift entrances, cuts out the coal of the upper breasts on both sides of the basin; but one gangway on the S. dip passes under the stream. W. of the Creek the coal has been worked 400 yards. The extreme width of the basin from outcrop to outcrop, where the ground is highest, is 1100 feet. The N. dip of the basin at the Swatara is 25° or 30°. W. of Big Creek it augments to 70°, and rapidly falls off to 9° near the W. end of the gangway. The N. dip is quite uniform from 10° to 20°. The coal in this mine averages 6 feet in thickness.

The Upper Coal, or Big Vein, is wrought in a manner quite similar to the preceding. The mining of this bed demonstrates the fact that the bottom of the basin does not sink W. except for a short distance near the E. end. For this reason a gangway is opened along the axis, and coal is wrought from the breasts on both sides. The coal is mined W. 1200 yards. The subdivisions of the bed are as follows:—

Shelly coal, 1 foot; Coal, 5 feet; Coal, 3 feet; Bone Coal, 1 foot; Coal, 2 feet.

The shipments from this colliery, in 1857, were 93,388 tons.

Oliver's Colliery (formerly M'Creary's)—Forest Improvement Company's Lands.—This colliery is based upon the seams wrought by Brown and White, though lying on the S. side of the anticlinal (**N**) ranging S. of Fisher's Basin. On the W. side of the Swatara, the lower or "Little Vein" only is wrought above water-level, the Big Vein or Red-Ash Seam having been driven Westward 1500 yards. The Little Vein, dipping 40° S., is mined 260 yards W. The seam is somewhat thinner and less pure than in Fisher's Basin.

On the E. side of the Swatara the Big Vein or Otto White-Ash Bed is wrought from two gangways on the breast above water-level; the upper gangway 500 yards, the lower 750 E. The coal on the upper level, 100 yards E. of the drift-mouth, is influenced by a small wrinkle, which caused the gangway to turn N. for a short distance. A far more important flexure affecting the dip is encountered at the E. end of the upper gangway. At this point the anticlinal (**N**) S. of Fisher's Basin seems to expire, as it affects this coal, rapidly to the Eastward, causing a sharp turn at the gangway-level into E., and finally into a N. dip. The coal at this point is faulty and confused. This has caused a suspension of work in this part of the mine; but as the W. gangways from the Otto Mines on the same bed stopped in a fault but a short distance to the N. on South-dipping coal, it appears evident that a small basin intervenes, which, rising Westward, would cause a reverse curve of the gangway before it could resume an Easterly direction on the S. dip. The lower level seems to be experiencing the influence of the same disturbance. At this level a division in the bed occurs a fourth of a mile E. of the drift-mouth by the intercalation of a stratum of slate of too great thickness to be cut away. The gangway divides at this point; but in 500 feet distance, the rock having thinned away, the two branches reunite into one. In the upper level no such division occurred. The average normal dip of the bed is 35° S. In thickness it corresponds nearly to what we have seen of it in Fisher's Basin.

Fisher's Basin seems to have expired so rapidly to the E. by a flattening-out of the dips, that its effects are not traceable on the E. side of the Swatara, and every attempt to find it developed as a basin of coal has failed. We see exhibited here the fact of a synclinal and anticlinal flexure, both expiring so rapidly in the same direction as to develop only a trifling subsidiary change of dip on the flank of the great anticlinal of the Swatara Falls.

The yield of Oliver's Colliery, in 1857, was 9638 tons.

J. C. White's Colliery (Forest Improvement Company's Lands).—The seam here wrought crops out at water-level 150 yards S. of Oliver's Big Vein. It is regarded as the "Grey-Ash Vein" of the Otto Mines. Dip, S. 45°. Gangways are driven at water-level 800 yards W., and 750 yards E. The subdivisions of the seam, under favourable circumstances, in the W. gangway are as follows:—

Coal, 6 feet 6 inches; Dirt undermining, 2 inches; Coal, 1 foot 8 inches; Dirt, 1 foot 2 inches.

In the E. gangway the following section was taken near the face of the gangway:—

Coal, 4 feet; Bone, 1 foot; Dirt, 1 foot; Shelly Coal, 3 feet.

A slope was recently sunk 80 yards on the same bed below water-level. In 1857, 23,369 tons of coal were shipped.

Dundas Colliery, No. 6, Sharp Mountain, E. of Tremont, or Bettinger Tunnel (Lessee, John Doherty).—This tunnel, 2½ miles E. of Tremont, enters Sharp Mountain 80 yards above water-level, and intersects six beds of coal, viz.:—

185 feet to 5-feet bed; dip, 30° S.; not worked. + 215 feet to 6-feet soft coal; dip, 36° S.; gangways, 300 yards E. and W. + 76 feet to 2-feet bed; dip, 52° S. + 120 feet to 4-feet bed. + 170 feet to 10 or 12 feet bed; dip, 45° S.; gangways, 300 yards E., and 250 yards W. + 120 feet to coal, subdivided by 2 feet 6 inches of slate into an upper member 6 feet thick, and a lower 2 feet 6 inches thick: this seam dips 45° S. The last two seams only are mined by gangways E. and W. The tunnel is now being prolonged Southward to other beds of coal.

MIDDLE CREEK.

Woodville Colliery (page 179 of text)—L. S. Spangler—situated on Middle Creek, in and immediately S. of the Westward prolongation of Fisher's Basin.—The Ten-feet Seam of the Donaldson Section has been wrought in the centre of the basin on the E. side of Middle Creek. 50 yards E. of the mine-entrance the basin deepens so rapidly as to require two gangways to give access to the coal on its two sides. The N. dip of the basin is 15°, the S. dip 25°. The N. gangway is 400 yards long; the S. gangway 300 yards, to a point at which it bears off Southward around an anticlinal subsiding Eastward. At this point, along the E. dip, a slope is sunk 85 yards, and gangways driven a short distance W. in the basin, and S. on the saddle.

On the S. side of the saddle the same bed is now wrought from Middle Creek at water-level: it dips 35° S. The gangway is driven 60 yards E., the dip growing flatter as it advances. The seam contains 7 or 8 feet thickness of coal. It is subdivided by slate sometimes 2 feet thick. On the W. side of the Creek a gangway is wrought 1000 yards W.

The Big Seam of Donaldson is wrought at water-level on both sides of Middle Creek. The gangway W. runs 1300 yards, the gangway E. 400 yards. On the W. side the seam is 20 feet thick, including the usual middle slate. On the E. side the whole seam dwindles to 8 feet thickness.

The Black Heath and "Primrose" (Black Valley) seams have also been wrought; the latter by gangways E. and W. at water-level, the former by a gangway W. It is reached by a tunnel from the Primrose gangway driven 26 yards N. Dip, S. 40°. It is proposed to sink a slope on the Big Seam during the present season. Shipments from this and the Spohn Colliery at Tremont, for 1857, 30,514 tons.

DONALDSON.

Broad Mountain Colliery (page 181 of text)—N. of Donaldson—R. H. F. Horton.—A tunnel, of which, so far as it was completed at the time our measurements were made, we have elsewhere presented a Section, is driven Northward into Broad or Thick Mountain. This tunnel intersects all the important lower seams of the Donaldson Section. From the entrance it is 141 yards long to the "Primrose" (Black Valley) Seam; 174 yards to the Black Heath Seam; 268 yards to a 4-feet seam; 288 yards to the Big Seam; and 384 to the Ten-feet Seam. Between the last two important beds two small impure beds were passed; the lowermost of these is known as the "Iron-ore Coal." The dip of the beds ranges from 50° to 60° S.

The Primrose Seam, which has yielded from 5 to 7 feet thickness of coal, is driven 1700 W. The Black Heath Seam varies in thickness from 3 to 12 feet. It has been wrought 480 yards E., and 1320 yards W. The Big Seam, the only one now wrought from the tunnel, is driven 500 yards E., and 1850 yards W. It is subdivided by a slate of variable thickness, between 6 inches and 6 feet, into an upper bench of 12-feet coal, and a lower one of 9 feet 5 inches. In common with all the others, it is more or less liable to compression, and consequent faulty structure. The Ten-feet Seam measures 10 feet in thickness, inclusive of a middle bench of bone coal and slate 2 feet thick.

The Big Seam is mined below water-level from a slope sunk 185 yards from the surface. The slope intersects the tunnel gangway 4 yards W. of the tunnel. Dip, 54° at top and bottom, 64° midway. Gangway, 600 yards W. and 400 yards E.; dip, 70° at the end of W. gangway. From the gangway, 200 yards W. of the slope, a tunnel is now being driven Northward to cut the Ten-feet Seam.

A new slope is sunk on the "Primrose" Seam about 150 yards E. of the tunnel. Length below surface, 110 yards; S., dip 54°. Gangways are started from the slope. It is designed to tunnel N. from the gangway to the Black Heath Seam.

Shipments in 1857, 58,838 tons.

Spohn Colliery (page 183 of text)—L. S. Spangler—near Tremont.—The two main N. and S. anticlinal flexures of the Little Lick Mountain drooping Eastward, and the included basin rising Westward, have very materially affected the simplicity of the mine at this colliery. A drift enters at water-level, and follows a small slate-seam, 150 yards Westward, dipping N.; a tunnel is then cut 40 yards S to a "Four-feet" seam of coal, dipping steeply N.E. from the subsiding main Southern axis of Little Lick Mountain. Followed Westward 25 yards, the saddle rises so rapidly in the same direction as to throw off the coal on its flanks, dipping N. and S. The S. gangway, driven 900 yards W., is deflected Southward owing to the Westward rise of the basin included between the anticlinals of Little Lick and Red mountains, and swings round to the S. side of the basin.

The N. gangway is driven 400 yards Westward to the rise of the basin between the anticlinals of Little Lick Mountain; it then swings Northward and Eastward, until, in a short distance, it sweeps round the N. saddle and again ranges Westward. On this N. side of the Northern axis Mr Eckel has penetrated to the seam by a tunnel at a higher level than Spangler's Gangway, and has driven the gangway Westward, until it begins to turn Northward under the effect of the Westward ascent of the basin between Little and Big Lick mountains.

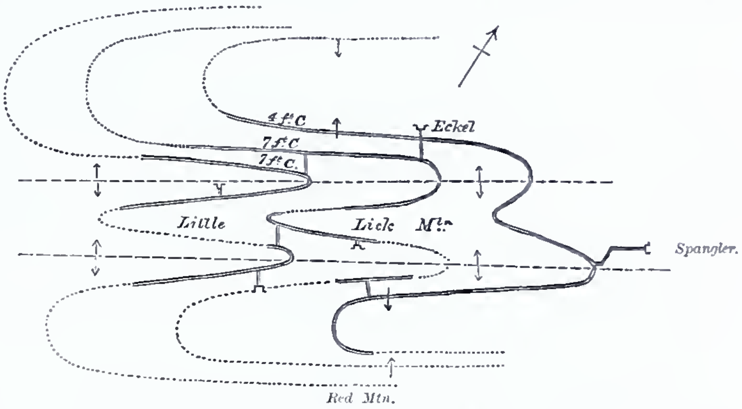


Fig. 313.—Diagram of Spangler and Eckel's Gangways.

From the "Four-feet" Seam, Eckel's Tunnel is prolonged 64 yards S. to the "Seven-feet" Seam. This bed was wrought Westward and Eastward round the Northern anticlinal. The same bed is entered by Spangler from his S. gangway on the Four-feet Coal, but it proves too impure to mine at that point. It has been wrought to a limited extent on the N. side of the S. axis by a tunnel from the surface.

From Eckel's Gangway, on the Seven-feet Seam, and also from several points on the surface, tunnels are driven to a still lower seam of coal than the preceding. It is locally known as the "New Seven-feet" Seam, or Wolf's (see Plate VII.), and is affected by the several flexures of the mountain in a manner precisely similar to the beds already described. The extraction of coal at the colliery is now entirely confined to a gangway on that part of the bed which dips Southward from the Southern axis of Little Lick Mountain. The Four-feet Seam has yielded, on an average, 4 feet thickness of coal; the two other seams about 5 feet each.

RAUSCH CREEK.

Mount Eagle Colliery (page 184 of text)—H. Heil and Co.—The great anticlinal of Little Lick Mountain, which enters the coal-field from the Williams Red-Shale Valley at "the Kettle," as it droops slowly Eastward, is arched above water-level by higher and higher measures, until, on Rausch Creek, the Great Upper Egg-Conglomerate descends beneath water-level, and the "Ten feet" and "Big" coal-seams of the Donaldson Section repose under high ground on the E. side of the creek.

At Heil's Colliery, a tunnel starting from the surface, near the outcrop of the "Ten-feet" Seam, is driven a few degrees E. of N. 100 yards, through higher and higher measures to the Big Coal, which dips 30° N. 10° E. In the tunnel several thin bands of coal and coaly matter were passed. The Big Seam includes an upper bench of coal from 10 to 12 feet thick, separated, by slate from 9 to 12 feet thick, from the lower coal 6 or 8 feet thick. Portions of the seam are wrought from parallel gangways, except where the intervening slate becomes so thin as to admit of being readily cut away. When the slate is thin, the coal is correspondingly thick.

From the tunnel, parallel gangways are driven South-Eastward, but they gradually deflect more and more S. as the coal sweeps round the point of the saddle to take its position on the S. side. The gangway on the upper bench is 400 yards long; on the lower, 300 yards. In the opposite direction from the tunnel two gangways are driven on the N. dip of the coal 300 yards, when the slate division becomes thin, and is cut away, one gangway only being pushed forward. This is driven 500 yards. At the present date some symptoms of a turn of the gangway towards the N. begin to manifest themselves. It is not improbable that such a change of direction will actually occur, as the coal may be affected by the shoaling or rising Westward of the basin included between the double anticlinal flexure of Little Lick Mountain, as we have seen to be the case with higher coals near Tremont.

An extension of the tunnel to higher seams is now in progress. The Black Heath Bed, it is expected, will be reached in 150 yards.

Shipments in 1857, 44,433 tons.

Lorberry Creek—Wheeler and Miller's Colliery.—From Rausch Creek, the Big Seam is indicated by an outcrop on the S. side of the anticlinal of Little Lick Mountain to the valley of Lorberry Creek. At the head of this valley a tunnel is driven 130 yards N. to it. Several unimportant coal-seams were cut in the tunnel. The prevailing subdivisions of the seam in this mine are as follows:—

Coal, 5 feet; Slate and Dirt, 2 feet 6 inches; Coal in four benches, 12 feet.

Dip 30° S. From the tunnel a gangway is driven E. 1600 yards. In this gangway, 500 yards E., the coal was compressed and shelly for 200 yards.

A slope is now being sunk from the gangway 60 feet E. of the tunnel. This slope descends obliquely upon the dip at an angle of 25°. It will be 200 feet long to the level of Kitzmiller, Stees, & Co.'s old gangway.

Shipments in 1857, 22,248 tons.

Kitzmiller, Stees, & Company's Colliery.—On the S. side of the basin opposite the colliery last described, the Big Seam has been wrought at water-level, and is now mined from a slope below water-level. The water-level gangway, following the coal W. on a N. dip of 30°, when 700 yards from the entrance, turns N. round the rising basin of the coal, and ranges E. nearly to Wheeler and Miller's Tunnel. The E. dip in the basin is 18°, the S. dip 30°. Width of the basin, about 500 yards.

The slope is sunk on the N. dip, near the drift-mouth. It is 100 yards long, dip 30° at top, 35° at bottom. The gangways are driven 320 yards W. and 180 yards E. In the slope the seam is 17 feet thick; but the middle bench of slate and dirt is 5 feet thick, and the lower coal consequently thinner than in the water-level gangway.

Shipments in 1857, 12,655 tons.

The anticlinal of Red Mountain ranges a short distance S. of the colliery. The Big Seam has been proved on its S. dip, but the subsidence of the arch E. carries it below water-level on Rausch Creek, as our section shows.

Sharp Mountain Colliery (page 186 of text)—Charles Molley & Co.—E. side of Lorberry Gap of Sharp Mountain.—Slope sunk 80 yards on the Umberhauer Red-Ash Seam, at an angle of 65° S. Gangway E. 350 yards and W. 300 yards.

The coal varies in thickness from 18 inches to 3 feet. It is underlaid by Bone coal and slate, and capped by dirt "undermining." In parts of the mine the coal has been compressed to a thickness of a few inches by irregularities in the top rock. The length of breast worked is 65 yards to water-level.

Shipments in 1857, 7240 tons.

The Dauphin Coal-Basin is now entirely deserted by coal miners; for several years little or no coal has been shipped from it. So unreliable do the seams prove, and so great is the outlay required, that, recollecting that former experiments have failed, no disposition at present is manifested to develop its resources.

BEAR GAP.

Wiconisco Coal-Basin, Bear Gap (page 189 of text).—In the Wiconisco Coal-basin at Bear Gap, two companies are engaged in the mining of coal, the Lykens Valley Coal Company, and the Short Mountain Coal Company. The operations of these companies are now entirely confined to the two lowermost seams of Lick Mountain, known as Nos. 1 and 2. The former company mine E. from the Gap, the latter company W.

Lykens Valley Coal Company's Mines (Superintendent, Mr Hoffman).—The lowermost, or No. 1 seam of the Bear Gap, situated scarcely 100 feet above the Umbral red shale, is followed by a slope sunk 90 yards N. at an angle of 45° at the top, declining to 18° at the bottom. From the foot of the slope a tunnel is driven 76 feet N. to the overlying No. 2 seam. In this tunnel, 30 feet above No. 1, a seam of coal-dirt 5 feet thick is cut.

Upon the No. 1 seam a gangway is driven E. from the slope 372 yards. A small double roll occurs 142 yards from the slope, which throws the seam 24 feet S. of its previous line. Upon the No. 2 seam a gangway is driven 68 yards W. and 600 yards E. In this gangway, 60 yards E. of the tunnel, the seam makes an offset S. 30 feet to the dirt underlier, with which it ranges E. No marketable coal has yet been obtained from the No. 2 coal in the slope. The bed varies from 8 to 12 feet in thickness, without dividing-slates; it is almost immediately overlaid by pea and nut conglomerate. A new slope is about to be sunk on the No. 2 seam. The No. 1 bed is between 5 and 8 feet in thickness. Both seams have been wrought very extensively above water-level by the Lykens Valley Coal Company. The Big Seam has been driven a mile and seven-eighths E. from the Gap. The lower seam is also wrought in the same direction, but it is generally too soft to bear transportation. By the thinning of the intervening strata 3600 feet E., the two beds approach within two feet of one another, and range forward as one great bed. The breast or slant length of these seams above water-level, from the Gap E., is said to exceed 500 feet; dip, 45°. They outcrop on the S. slope of the Lick Mountain, about 300 feet below the summit. On the N. side of the North or Bear Mountain, the same seams are proved about the same distance below the crest, and but a little way above the red-shale alternations. At this point the seams are somewhat thinner.

Shipments, in 1857, 65,202 tons.

Short Mountain Coal Company's Mines (page 191 of text)—Superintendent, A. B. Young.—The mines of this Company are situated in the Short Mountain, or prolongation of the Lick Mountain W. from Bear Gap. The general strike of the measures is S. 78° W. for two miles, to the high notch of Big Run, at which, owing to the effect of a double anticlinal flexure throwing E. dips into the valley, the trend of the coal-seams is N. 12° W. for 300 yards, and is again almost due W. for 1½ miles to the extreme W. end of the basin, from which the outcrop follows the N. side of Bear Mountain E. The only seams of profitable value traced through this range of country are Nos. 1 and 2, already wrought to a great distance E. At Big Run Gap, and at the extreme W. end of the basin, openings are made in both beds, which are mined to a small extent for the supply of farmers. At Bear Gap the Big Seam (No. 2) is entered by a drift above the water-level, and a gangway is driven W. 1670 yards. At convenient points tunnels are driven S. to the No. 1 seam, upon which gangways are driven parallel, and equal in extent to the former. The intervening rock is generally a dark-blue or black shale, sometimes very silicious and hard; it varies in thickness from 8 to 30 feet. Near the Gap, on a dip of 28° N., the breast is 170 yards long, but at the end of the gangway, where the dip is 18°, though steeper towards the outcrop, the breast is 270 yards long. On account of the length of breast, and the gentle character of the dip, self-acting planes are constructed inside of the mine—four on each seam—upon which the empty cars are raised sidewise on a safety-truck, and at suitable points pushed into the chambers, which are cut out along the dip at right angles to the planes. Frequent bulges or convexities in the bottom slate, causing curvature of the gangways and breasts, occur in the mine. The prevailing thickness of the seams is about the same as we have already noted. It is a somewhat singular circumstance that the two beds are rarely both in a sound condition in the same neighbourhood; one is usually soft and dirty when the other is hard. This is also true of the same beds going E. The No. 2 coal is considered superior in quality to the lower bed.

Shipments in 1857, 56,538 tons.

The tunnel driven N. across the centre of the basin opposite Bear Gap has been abandoned these seven or eight years. It is cut 1110 feet to the Hoffman Coal; and from the gangway on this bed 500 feet E., is prolonged 200 feet through several thin seams into the conglomerate. The only seams wrought to any extent are the Etting and Pat Martin. Neither of these is certainly recognisable in the tunnel, where the measures are greatly confused and broken up, but the former was cut by a short tunnel driven S. from the "air-hole coal" about 500 feet E., and the latter by a second tunnel driven S. from the Etting seam. The Pat Martin is worked about two-thirds of a mile E. of where it was struck, the Etting a mile E. Driving W. on the Etting seam, the gangway turns S., then E., and finally S. again, owing, in the first instance, to the rise of a basin W., and in the last, to a saddle drooping E. This tunnel was driven and used for years by the Lykens Valley Coal Company; but the experiment was a costly one, and proved unprofitable.

About 4 miles E. of Bear Gap an attempt is now being made on the Beuhler lands to tunnel N. through the Lick Mountain to the Coal-measures. The experiment is a hazardous one.

MINE-HILL VALLEY.

Wm. Richardson's Colliery—located on Wolf Creek, E. of Mill Creek Gap, in the second basin N. of Mine Hill.—A perpendicular shaft is sunk in the centre of a synclinal basin, through sand and debris 75 feet, to the Jugular Bed. The upper portion of this great bed seems to have been swept away, leaving a band of coal divided by slate variable in thickness, the average yield of which is 12 feet of coal. The dip of the coal on the N. side of the basin is perpendicular, or rather N.; on the S. side the dip is gentle. The basin rises gradually to the E. From the rising gangway, 250 feet E. of the shaft, a tunnel is cut N. 75 feet, to a lower coal-bed 3½ feet thick. This seam has been mined at water-level on the slope of Broad Mountain. Two other seams, one 7 feet 6 inches thick, lying 100 feet N. of it, and another, 150 feet lower in the series, have been mined above water-level on the flank of the Broad Mountain. These seams dip nearly vertically opposite Mill Creek Gap of the Mine Hill, but flatten as they range E. to sweep round the rising basin of the Big Coal.

No coal has been shipped from this mine for several years.

Repplier's Colliery (page 202 of text)—Lessee, George S. Repplier (formerly Lawton), situated on the N. side of Mine Hill, at Mill Creek Gap.—This slope descends W. upon the bottom slate of the great Johns' Bed (provisionally termed the Jugular), as the basin of that coal rises Eastward. The inclined plane does not follow the axis of the basin, the bearing of which is S. 70° W. Length of slope to first level, 401 feet; to lower level, 996 feet. The dip is 21° in the upper lift, and 19° in the lower. The upper-level gangways sweep round the end of the basin into regular N. and S. dips. On the S. side of the basin, 600 feet from the slope, a cut extends Northward through the 7-feet coal-bed, here quite thin and unimportant, 235 feet to a 2 feet 6 inches bed, which was previously supposed to be 11 feet thick. It was struck at the centre of the rising basin. Its regular N. dip is 46°, the S. dip 29°. The bed was mined on both sides of the basin to a limited extent, and is now abandoned.

The lower gangways from the slope curve similarly to the upper, keeping the bottom slate of the coal as it dips W., S.W., and S. on the one side of the slope, and N.W. and N. on the other. Where the normal S. and N. dips first set in, the gangways ranging W. are 400 feet apart; whereas 2000 feet W. of the slope, the present limit of the workings, they are 240 feet asunder. This is due to the contraction of the basin and the increased steepness of the dips in that direction.

Newcastle Colliery, in Kelly's Hollow (page 203 of text)—A. Hexter & Co. (formerly Fogarty & Kelly)—situated in the second basin N. of Mine Hill, W. of Mill Creek Gap.—The upper-level workings (now abandoned) were begun by a drift cut Westward upon the bottom slate of a great bed of coal dipping 25° S.W. of the entrance 250 feet: a cross-cut was made through coal 190 feet to the top slate; the latter was passed through by 20 feet of tunnel to a second bed, dipping steeply S. These seams form a sharp synclinal basin, and rise again to meet the cross-cut prolonged to the lower bed, which dips 56° N. Gangways are driven W. upon both sides of the basin of the lower coal and on the S. dip of the upper. The S. dip of the lower bed in the main gangway is pretty uniform, whereas that of the upper varies greatly in the same direction; it is very gentle 500 W. of the cross-cut, whereas 1000 feet W. it is nearly vertical.

The new opening at these mines is a tunnel cut N. 30° W. from the surface 65 feet below the level of the old cross-cut. The basin of the lower coal is 8 feet above the tunnel-level 510 feet from the mouth. In driving this tunnel an anticlinal was passed 160 feet S. of the axis of the basin. On either side of this arch three small coal-seams dip opposingly; but a fourth seam, comprising 8 feet of coal and slate, overlying the smaller beds on the S. dip, was not found on the N. The rocks intervening between the smaller seams are much thinner on the N. than on the S. side of the anticlinal axis; whether there is a similar though far greater thinning of the strata lying above and below the 8-feet seam, so as to cause that bed to merge into the great lower bed in the basin with but a thin division of slate, or whether the 8-feet seam swells out into the enormous mass of coal which is wrought at the tunnel, are questions which, in the present state of the mining, do not admit of solution. From the tunnel-mouth it is 100 yards S. to the outcrop of the great seam dipping S. into the gangway of Repplier's

(Lawton's) Mine. It seems evident, therefore, that we must regard one or other of the large beds in the basin as the Repplier seam, or else suppose the Repplier Bed the equivalent of both, exclusive of the addition of the 8-feet slaty bed of the tunnel.

The long-vexed question of the existence of horizons of deposit of two great White-ash beds at the base of the Coal-measures in this part of the coal-field may, in the future, be settled to the satisfaction of all by the further extension of the mining at this colliery.

So far as we have present facts, the synclinal axis in the tunnel seems to deepen Eastwardly.

Amount shipped, in 1857, 2062 tons.

Patterson Colliery—Wm. Littlehales & Son—situated on the Slope of Broad Mountain, half a mile E. of Miller's Pine-Knot Slope Mine.—There is a drift 75 feet above water-level on the Jugular Bed, dipping 45° S. The main gangway is driven E. 500 yards on the bottom slate of the coal. The thickness of the seam is exceedingly variable, but the following will represent its subdivisions :—

Coal, including thin slates, in some places exceeding 30 feet, in others entirely absent ; Slate, 6 feet 9 inches ; Coal, 1 foot 6 inches ; Bony Coal, 8 feet 12 inches : (these divisions are at times represented by 3 or 4 feet of slate and dirt) ; Bottom Coal, from 5 to 6 feet.

About 350 yards E. of the mine-entrance the upper division is separated from the lower by the intercalation of a stratum of conglomerate rock. A branch gangway follows the great upper bed : in working the breasts upon this, the overlying slate is occasionally so thin as to fall, bringing with it 3 feet of coal from an upper seam. The lower division of the bed wrought from the main gangway does not exceed 6 feet thickness of sound coal : it is underlaid by pebbly sandstone.

In a drift on the same level mined W. 300 yards, the seam was quite regular ; no rock was found in it, and the slate division does not exceed 2 feet.

Yield, in 1857, 14,247 tons.

Pine Knot Colliery (page 204 of text)—Lessee, Charles Miller (formerly, Adams & Miller)—situated on the S. Slope of the Broad Mountain, E. of West Branch Gap of Mine Hill.—The slope descends S. with the middle benches of the Mammoth Coal-bed, the bottom slate of which is followed only through the lower part. Length, 120 yards. Dip of coal, 40°. The gangways E. and W. from the slope are each upwards of a mile in length. At the foot of the slope a tunnel is driven S. 92 feet to the Lelar Coal, which is from 5 to 7 feet thick, and is prolonged 107 feet to the Crosby Bed, from 9 to 14 feet thick. These beds have not yet been mined.

A new slope is sunk 100 yards from the outcrop to the end of the W. gangway from the old slope. The inclination of the Mammoth Bed at this mine is 44° S. From this slope a tunnel S., 220 feet long, is cut to the Crosby Coal, passing through the Lelar, both dipping S. somewhat more steeply than the Mammoth. E. of the Pine Knot Slope the Lelar Coal is sometimes found separated from the Mammoth by so thin a partition of slate as to admit of being mined at the same time. The Mammoth Seam, the normal thickness of which is 20 feet, varies greatly in the same direction. It has been developed as a mass of coal exceeding 60 feet in thickness ; but under these circumstances, it is shelly, and more or less impure. W. from the Old Slope the coal-seams are more regular and uniform in thickness, and the intervening measures are thicker.

The yield of the Pine Knot Colliery, in 1856, was 34,497 tons ; in 1857, 22,767 tons.

Lewis Dougherty's Mine at the Mine Hill Gap, and Hill's Tunnel, a mile W. of the gap, are both abandoned.

Kear's Mammoth Colliery (N.W. side of West Branch Gap)—Slope sunk on the bottom slate of the Daniel or Mammoth Seam 120 yards below the surface. Dip 50° at the top, increasing to 80°, and decreasing at the bottom to 50°. Gangway driven 50 yards E. and 1600 yards W. From the foot of the slope a tunnel is driven 37 yards N. to an 8-feet seam, dipping 50° N. : upon this a gangway is driven 150 yards W.

The Mammoth or Daniel Bed in this mine averages fully 20 feet in thickness. Except an occasional layer of Bone coal or thin slate, there are no impurities in the bed. It is sometimes as much as 30 feet thick.

Jugular Colliery (page 205 of text)—John M'Ginnis—situated on the S. Side of the Broad Mountain immediately opposite Kear's Slope on the Mammoth Seam.—The slope is sunk 57 yards below water-level on the bottom slate of the Jugular Seam, dipping 45° S. At the bottom of the slope the coal was only a few inches thick on the E. side, but on the W. side it was 4 feet thick, and in the gangway increased steadily to 28 feet. In the breasts opened W. its thickness is pretty uniform; but in the gangway it is variable. The gangway is driven W. 275 yards. The old workings on the coal above water-level W. have been on fire 19 or 20 years.

The Jugular Seam has been worked E. on the breast above water-level more than 400 yards. In this drift the bed sometimes exceeds 30 feet in thickness. The tumbling or dirt-bed occasionally approaches the Jugular so nearly, by the thinning of the measures, as to fall into the breasts on the latter bed. At water-level the Jugular is cut out by rock.

The yield of the colliery in 1857 was 8163 tons.

Heckscherville Colliery (page 207 of text)—Lessee, E. Borda.—The present and former workings of this colliery are very extensive. The avenues to the coal embrace a water-level tunnel, two slopes and two tunnels below water-level.

The water-level tunnel, formerly known as Paine's, penetrates the Broad Mountain, which it enters 150 feet above the level of Mine Hill Gap, nearly opposite Taylor & Volpert's* Colliery. A section of the strata cut by this tunnel has been already presented. The only seams wrought from the tunnel are the Daniel and the Jugular. Upon the former, gangways are driven nearly 2000 yards W.; upon the latter, 1700 yards. A counter-level gangway, entering the Jugular Seam from a ravine half a mile W. of the tunnel, extracts the upper breast of the coal: it is 800 yards long.

One hundred feet E. of the tunnel a slope is sunk on the Lelar Bed, a seam of unimportant thickness next overlying the Daniel Coal; length of slope below tunnel level, 205 yards, dip 45° S. at top, augmenting to 50° at bottom. The Crosby Seam, ranging 12 yards S. of the Lelar, is tunneled to from the foot of the slope. From the gangway on this bed, 55 yards W. of the slope, a tunnel is driven N. across the Lelar Coal 73 yards to the Daniel Seam, dipping 47° S. In the opposite direction a tunnel is cut 41 yards to the "New Vein" coal, dipping 58° S., and is prolonged 53 yards to the Church Seam, dipping 60° S. W. of this tunnel, 42 yards from the Church Bed, a cross way is cut 10 yards S. to communicate with a vertical shaft sunk 40 yards from the surface. This shaft is designed to drain the constantly-extending underground gangways of the mine: it is fitted with a variety of the Cornish "Bull" Engine, and two pumps designed to lift 326 gallons of water per stroke.

In sinking the shaft a small seam, commonly called the Red-ash Bed, was cut. From this shaft a tunnel was driven S. to cut this seam; but, contrary to expectation, the dips of the measures changed 30 feet S. of the shaft, and the coal which basins at a higher level was not struck. The opposing dips amount to 45° on either side of the synclinal. The presence of this synclinal about 300 yards N. of the outcrop of the same measures on the S. side of the valley bordering Mine Hill, has raised the question whether the anticlinal of Peaked Mountain, the topographical indications of which expire three-fourths of a mile to the W., will not materially influence the simplicity of the general basin, and in the future affect the deep workings of the lower coals. Looking to the steepness of the N. dip of the strata and the known persistency of great anticlinal flexures in the strata after their effects are topographically lost, we can hardly hesitate to infer that the anticlinal of Peaked Mountain has not entirely subsided on the cross section at Heckscherville.

From the North and South Tunnel, already described, cutting all the strata from the Church down to the Daniel seam, the Crosby and Daniel coal-beds are mined 2000 yards W. At the end or face of the gangway the Daniel Coal measures 15 feet in thickness, including a band of slate 2 feet thick ranging through the bed 8 feet from the bottom: above this slate the coal is often dirty and impure. The slate is not always present.

The Crosby Seam is very faulty W., but little coal is now taken from it. The "New Vein" is a double bed, having 6 feet of coal overlaid by 4 feet of slate, which in turn supports 4 feet of coal. The gangway upon it is a fourth of a mile long. The Church Seam is 12 feet thick where it was struck by the tunnel; but 50 feet E. it is only 3 feet thick at the floor of the gangway, and two dips appear in the bed. Near the cross-cut to the shaft there is but little coal in the seam; the entire thickness is replaced by slaty coal and slate.

For facility in gaining access to the mine, a slope is established on the Crosby Seam, about 125 yards W.

of the old slope. Seventy yards W. of the New Slope from the Crosby Seam gangway, a tunnel is cut S. to the New Vein, and N. to the Jugular Seam. The strata cut in this tunnel, with the intervals between the coals, agree almost precisely with those at the water-level tunnel (Paine's), except in the measures between the Jugular and the big overlying Dirt-bed. This bed is greatly expanded; but the rock beneath is proportionally diminished in thickness. The Jugular Seam is 24 feet thick at the end of the tunnel. It is but newly opened to mining at this level, and no coal has been taken from it. Shipments, in 1857: from Old Breaker, six weeks' work, 5049 tons; from New Breaker, nine and a half months' work, 61,538 tons. Estimate aggregate capacity for 1858, 140,000 tons.

Pumping Engine.—Allusion is made in the foregoing description of the Heckscherville Colliery to the powerful pumping-engine designed to lift the water from this and such of the neighbouring mines as may communicate with it. We append a more precise description, furnished by Mr Harrison, who supervised its construction in the shop of George W. Snyder, of Pottsville.

The steam-cylinder stands vertically upon its bed-plate, which rests on massive stone abutments. The diameter is 50 inches, and stroke of piston 10 feet. The action is direct upon two pumps, each 20 inches in diameter and 10 feet in the stroke. The delivery-pipes are each 100 feet high, and 20 inches in diameter, lined with wood, and supplied with valves of a kind of bell-metal, which will resist the corrosive waters of the mine. The entire weight of metal in the structure is said to be 160 tons.

Three smaller engines of a similar description are at work in the coal region; one at Thomaston Shaft, another at Monterey (Graham's) Shaft, and the third at the Otto Shaft.

Taylor and Volpert's Colliery—situated on the N. Side of Mine Hill, 1 mile W. and 185 feet above the water-level of West Branch Gap.—A tunnel enters S. into Mine Hill, 43 yards to the Daniel or Mammoth Seam, upon which a gangway is wrought 760 yards. W. of the tunnel 340 yards, a tunnel is driven 20 yards S. to a small seam under the Daniel. It is not pure, and is worked but little. In the main gangway at this tunnel an engine was placed, and a slope sunk 100 yards; from this, gangways are driven 220 yards E. and 180 yards W. The accidental ignition of the coal in the mine by fire from the boilers, has caused the abandonment of this portion of the mine.

A new slope, 100 yards long, is now being sunk at the back end of this main tunnel. In this mine the Daniel Seam is from 7 to 8 feet in thickness, except in one part of the W. gangway, where it is thicker.

The shipments, in 1857, amounted to 12,596 tons.

Thomaston Colliery (page 207 of text)—R. Heckscher & Co. (Forest Imperial Company's Lands).—The Thomaston Tunnel is situated 150 feet above the level of Mine Hill Gap, and 760 yards W. of Taylor and Volpert's. It enters from the surface about 20 yards S. of the crop of the Crosby Seam, and from the mouth timber is driven 122 yards S. to the Daniel Seam dipping 38° S. The Lelar, dipping 51° S., is passed in the tunnel 88 yards N. of the Daniel. The latter bed is wrought 2200 yards W.; the dip augments W. to 46°. Two short tunnels are cut S. from the gangway of the Daniel to a small underlying seam, which is worked about 800 yards.

The thickness of the Daniel Seam varies between 8 and 15 feet. It yields from 5 to 10 feet of marketable coal.

North of the tunnel mouth, 213 feet, a vertical shaft is sunk 230 feet to the Crosby Seam dipping 47° N. Upon this seam gangways are opened 160 yards E. and 370 yards W. The breasts on the coal are 100 yards long. The Crosby Seam is 13 feet thick: thus far it has proved rather shelly and impure.

The shipments from the Thomaston Colliery, in 1857, amounted to 41,443 tons, working eleven months. Capacity for 1858 estimated at 75,000 tons.

From the above reliable facts concerning the Thomaston Tunnel, it will at once appear how greatly we were misinformed in our notes upon the same colliery, printed on page 207 of the text. The distance to which the Daniel Seam has been mined W. of the Tunnel destroys the probability of the once prevailing conviction, expressed on page 211, of the shallowness of the S.W. Branch of the Mine Hill Basin.

Glen Carbon Colliery (page 208 of text)—Lessees, M'Farland and Werner.—We have already presented, on page 208, some account of this colliery, procured in 1852; we have now more accurate data, derived from mine surveys obligingly furnished by Mr C. M. Hill.

A tunnel 200 feet long enters N. into the Broad Mountain to the "Dirt Vein," or a mixture of coal and slate, corresponding in position to the Lelar or Slope Vein of Heckscherville. This was followed 200 feet W., and the South-dipping strata lying beneath are passed through by a tunnel 196 feet long to the "North Vein," which is to be regarded as a subdivision of the Daniel. In this tunnel several coals were cut as follows, with the intervals:—From the "Dirt Vein," 62 feet to a coal 2 feet thick, S. dip 38°; 60 feet to a coal 2 feet 8 inches thick; and 33 feet to the Daniel or Mammoth Bed, of which the thickness averages about 9 feet, including two thin seams of slate. This bed dips 45° S. at the tunnel, but steepens W. to 70°. The North Bed contains 5 feet of hard coal: it dips 42° S., steepening W. to 52°. At the tunnel this seam is separated from the Daniel by 40 feet of strata. In the gangway upon the latter, 3600 feet W. of the tunnel, this thickness has dwindled to 2 feet, and the two seams have been mined together. The gangway upon the Daniel Bed is 4000 feet long.

The gangway upon the North Coal is driven W. 1250 feet to a third tunnel cut N. 273 feet, through four small beds corresponding with those in Heckscherville Tunnel, to the top of the "Tumbling Vein," dipping S. 40°, from which it is 85 feet to the top of the underlying "Jugular Vein." The latter seam is in confusion at the end of the tunnel, owing apparently to the conflicting dips of a small saddle and basin which appear to end at this point. At its crop above the tunnel, the Jugular Seam has resumed its natural condition, and dips about 45° S.

The "Crosby Vein," lying 250 feet S. of the Daniel, is entered by a tunnel crossing the strata obliquely from the "Dirt Vein," and is mined W. 3500 feet, when it is pinched out. Upon this seam a slope was recently sunk 80 yards below the tunnel-level on the bottom slate, dip 55° at top, and 62° at bottom, and gangways are now working from this slope 500 yards W. and 160 yards E. The Daniel Bed is also cut on this lower level in a tunnel driven back 78 yards to it from the gangway, 35 yards W. of the slope. At the same distance E. of the slope a tunnel is cut 23 yards S. to a coal-seam 3 feet thick: it is not wrought. The Crosby is here developed as a fine bed of coal, ranging from 16 to 20 feet in thickness: a slate sometimes appears under the top bench, but it is otherwise quite free from impurities.

This colliery yielded, in 1856, 19,249 tons; in 1857, 20,908 tons.

Peaked Mountain Colliery (page 208 of text)—Lessees, Steel and Patterson (formerly Oliver).—A shaft is sunk 81 feet, from the bottom of which a tunnel is driven S. under the Peaked Mountain. It cuts four seams of coal at intervals, as follows:—52 feet to 11 feet bed, N. dip 50°; 149 feet to 12 feet coal-dirt and coal, N. dip 51°; 147 feet to Crosby Vein, 11 feet thick, N. dip 53°; and 360 feet to the Daniel Bed, 13 feet thick. Gangways are worked E. and W. upon each of these seams. The E. gangway upon the Daniel Bed deflects S. around the declining arch of the Peaked Mountain anticlinal; the breasts from the gangway level extend to the crest of the saddle over which the coal arches into a S. dip. The old water-level tunnel leading S. to the Crosby Vein is now abandoned. The shaft is to be extended downward 228 feet, to secure another breast upon the coal.

Yield of this mine, in 1856, 28,745 tons; in 1857, 29,410 tons.

J. F. Taylor's Colliery (formerly Taylor and Atwood's)—half a mile E. of Monterey, head-waters of West Branch.—Two water-level gangways or drifts have been pursued W. somewhat over a fourth of a mile. The seams wrought are not positively identified; one of them is in all probability the Daniel, the other the Crosby. Dip in both cases from 45° to 53° S.

On the S. Drift Coal or Crosby (?) Seam a slope was recently sunk 83 yards below water-level on a dip of 48° S. This bed is stated to be 8 feet 6 inches thick. The Daniel, a slaty and bony bed, is 9 feet thick.

This colliery shipped no coal in 1857.

Schollenberger's Glendower Colliery (situated on the N. Side of Peaked Mountain, S.E. of Taylor's).—At water-level, a tunnel driven Southward 37 yards penetrates the Crosby Seam, dipping 45° or 50° N. The gangway is driven 650 yards Westward. Breasts from 25 to 30 yards long.

Monterey Colliery—Agent, H. H. Dunn (formerly J. S. Graham).—This colliery is situated near the W. end of the coal-basin, which ranges at the S. base of the Broad Mountain. A slope is sunk on the N. side of the basin upon a seam which corresponds in position to the "New Vein" of Heckscherville. Length of slope, 65 yards; dip, 62°. The gangway E. is driven 600 yards, and that W. 500 yards. In the latter direction the gangway deflects Southward round the rising basin of the coal. The bed is 10 feet thick.

From the foot of the slope a tunnel runs 45 yards S. to the Church Seam, 5 or 6 feet thick. The gangway is driven 50 yards E. and 100 yards W.; but the coal proves shelly and poor. A tunnel, 50 yards long, is driven N. from the gangway 5 yards E. of the slope to the Crosby Seam. This coal is 14 feet thick, and free from slate. Gangway, 600 yards E., and the same distance W. This gangway also is affected by the rising basin. Dip at end of basin 10° E. At this point the coal is somewhat shelly and crushed. The breasts are upwards of 200 yards long. From the Crosby Seam, 60 yards E. of the entering tunnel, a tunnel is driven 87 yards N., passing three very small seams to the Daniel Bed, which is characterised by the same finely-laminated slate which overlies the bed at Heckscherville, and elsewhere to the Eastward. The seam is 8 feet thick, including 7 feet of coal. The gangway E. upon it is 60 yards long.

Shipments of coal in 1857, 27,570 tons.

Greenwood Colliery (Reed Improvement Lands)—situated on the S. Side of Peaked Mountain, S.W. of Schollenberger's.—A tunnel, at water-level, is driven N. 37 yards to a coal-seam dipping 45° S. The subdivisions of the bed are as follows:—

Bone Coal and Slate, 4 to 10 inches; Coal, 1 foot 6 inches to 2 feet; Coal, 4 feet 6 inches to 5 feet; Coal and Slate, 1 foot 6 inches to 3 feet.

The tunnel, prolonged, cuts through a seam 4 feet thick, separated from the preceding by 6 feet of slate, and, passing a leader 65 yards from the mine-mouth, is extended to a seam of rough coal 80 yards from the entrance. The last coal dips 37° S. The gangway on the main coal is driven 170 yards E. and 540 yards W. The dip declines Westward to 35°. We have no data guiding us to a certain determination of the equivalency of this seam, or whether it is higher in the strata, and how much higher, than that wrought at Rohrer's Colliery farther W. The tunnel is now being prolonged, in the expectation of cutting lower valuable seams.

No coal shipped in 1857.

W. Rohrer's Colliery (page 209 of text)—situated at the W. End of Peaked Mountain.—A slope is sunk 110 yards below water-level on a seam of coal dipping S. 40° at the outcrop, and 70° at the foot of the slope. The exact position of the bed in the series, and its equivalent elsewhere, has not been determined, but it is evidently quite low. The usual subdivisions of the bed are stated as follows:—

Coal, 3 feet; Slate, 1 foot; Coal, 5 feet; Slate and dirt, 10 inches; Coal, 3 feet; Slate, 1 foot 6 inches; Coal, rough, 4 feet.

From the slope a gangway is driven 400 yards Eastward; at the face the dip is 30° S., and the breast, to water-level, upwards of 140 yards. A roll in the coal causes an E. dip, along which an old water-level gangway sweeps N. for some distance, but has not affected the lower level.

The gangway driven 50 yards W. struck the basin of the coal rising Westward. Higher on the breast a counter-level is driven on a small anticlinal roll, which seems to expire Eastward, as it was not discovered in the slope. The rising of the basin alluded to causes the gangway to swing round into a N. dip, which, 40 yards E., changes to E. dip, and finally into S. This saddle thus developed, expiring Eastward, affects the gangway in the usual manner; the joint result of the rising basin and drooping saddle being a sigmoid curvature of the gangway. Ranging Westward, the anticlinal must pass along the S. side of Buck Ridge, but it has not been traced. On its flank the coal in the gangway is finally cut out, except the lower bench, which is nowhere of sufficiently good quality to be profitably mined, and the level is abandoned. We have no information of the distance to which it was driven before this fault appeared.

In 1857, 15,098 tons were shipped from the mine.

BOOK VIII.—*Continued.*

BROAD-TOP COAL-FIELD.

The next district which claims our attention, in a systematic description of the coal-fields of Pennsylvania, is the Broad-Top Mountain in Huntingdon and Bedford counties. The general structural features of this insulated table-land have been already noticed in Chapter I. of Division III. of Book VI., and again in Chapter V. of Division IV. of Book VI., where mention has also been made of its Vespertine and Umbral rocks, or its Lower and Middle Carboniferous formations. I have already shown, at Page 361, Vol. I., that this outlying coal-field occupies a midway position in the mountain-chain, in the same long synclinal belt which in the North-eastern corner of the State embraces the third or Northern Anthracite Basin. While its geographical relations link it thus with the Anthracite coal-fields, its geological analogies, especially the chemical composition of its coal, associate it rather with the great Bituminous Coal-region N.W. of the Alleghany Mountain, of which we may regard it as an outlier, as indeed we must, in strict sense, the Anthracite Basins themselves. Considerations of convenience induce me to describe this district in Book VIII., notwithstanding that all the coal included in it belongs to the semi-bituminous variety. Such an arrangement is justifiable even on strictly geological grounds; for as the Coal-measures of the Broad-Top Mountain, and the coal itself, are intermediate in type between those of the Anthracite and those of the Bituminous coal regions, they should occupy an intermediate place in any methodical account of the formation. Their deviation from the Bituminous Coal-measures is due to the same causes which have made the strata of the Anthracite fields to depart still more widely, namely, the same originally greater amount of shore action, and the same subsequently-exercised metamorphic agency, altering or de-bituminising the coal of the whole mountain-zone. Classified in accordance with the chemical nature of its coal, this coal-field relates itself quite as closely to the Eastern Anthracite basins as to the Western Bituminous ones. In the description it was shown that the coal of the Western extremities of the Southern and Middle Anthracite fields graduates from Anthracite into a dry semi-bituminous coal as we approach the Susquehanna, so that even there there is an approximation to the composition typical of the Broad-Top Field. In general terms, the proportion of volatile matter in this insulated coal-field does not exceed by more than a few per cent that of the coal in the Western end of the Dauphin Basin, while it falls short by a rather larger ratio that of the basins next W. of the Alleghany Mountain.

Boundaries of the Broad-Top Coal-field.—The detached coal-basin of the Broad-Top Mountain is situated centrally in the long synclinal trough of the Older and Middle Carboniferous Formations of the Fourth Belt of the Sixth District, described at page 528, Vol. I. The plateau of the productive coal-rocks is everywhere margined by the Seral Conglomerate, itself merely an underlying comparatively barren division of the Coal-measures. To the N. of this plateau lies Plank Cabin Valley, scooped in the softer Umbral Red Shale; to the W. of it stretches a deep narrow valley cut in the same formation, and bounded Westward by Terrace Mountain; to the Eastward is a similar narrow valley bounded Eastward by Sideling Hill; and to the S. a more irregular Red-shale valley, confined by Harbour Mountain, and called Well's Valley. Into Plank Cabin Valley and Well's Valley the Broad-Top Mountain projects a series of synclinal knobs or finger-like spurs, each of them marking the termination of a subordinate trough, or a sub-basin of the Coal-measures.

Area of Coal.—It is not practicable in the present imperfectly developed state of this Coal-field to estimate the area of its Coal-measures with exactness. My calculations indicate about 25 square miles.

Let us now proceed to a detailed description of the structure and contents of the Coal-field.*

The Seral Conglomerate in the Broad-Top Coal-field is to be regarded simply as the oldest or lowest of the sandstones of the Coal-measures. It is imperfectly exposed for measurement at the S. side. Beneath Savage's or Norris's Coal-bed, on Rocky Ridge, and Stambaugh's in North Wray's Hill, it would appear to be less than 150 feet in thickness. It is finely exposed for 50 feet above the alternating sandstones and shales of the Umbral and Seral strata in the Raven Rocks, 2½ miles S. of De Forrest's, at the gorge of Trough Creek. At this point hard and massive coarse-grained grey and greyish-white beds, tinged greenish, buff and brown, and from 2 to 4 feet thick, alternate with thin-bedded grey and brownish beds of sandstone, with a few seams of black shale full of vegetable impressions.

The upper members of the Seral Conglomerate are well exposed on Rocky Ridge at Savage's and Taylor's old openings on the lowest coal. Here a characteristic stratum, usually the floor of this coal-bed, a fine-grained massive sandstone, sparkling with mica, dips 30° S. 70° E. This rock is traceable by its angular fragments on the sides of Rocky Ridge, and on the opposite summit 1½ miles S. of Savage's, dipping 35° W. Beneath it is found a coarse brown micaceous obliquely-bedded sandstone 7 feet thick, reposing on massive white sandstone, made up of granules of milky quartz. Farther S. it becomes a fine white conglomerate. The same stratum appears on Round Top, near the Trough Creek Furnace, but not on the higher summit of Round Knob, near M^cLean's.

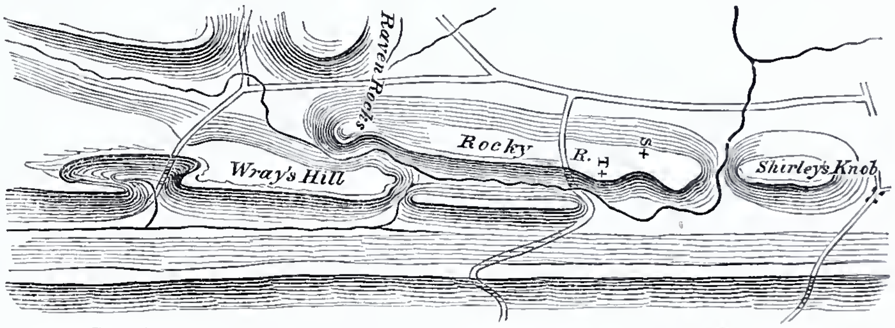


Fig. 314.—Topographical Sketch, Shirley's Knob, Broad-Top Mountain.

North Wray's Hill, at first a succession of short low knobs, along the E. side of Shirley's Knob and Rocky Ridge, becomes a ridge 3 miles S. of Cassville. It increases in height and breadth of summit S., and exhibits two crests, the Easternmost of which is cut by a deep wide gap, and is traversed by a feeble anticlinal roll, which flattens away at Deever's. The W. summit widens rapidly, and is soon capped by the undulating strata of the Seral conglomerate, over the surface of which spread the "Barrens." It is upon these that the lowest coal-bed—that opened by Stambaugh—appears. The conglomerate, estimating its thickness from the dip, cannot exceed 150 feet; nor does it exhibit a massive or conglomeritic aspect in all places. In the ravine between the two summits of Wray's Hill, massive fragments of fine white-grained conglomeritic sandstone are abundant. Three and a half miles S. of Stambaugh's openings upon the level surface of the hill, M^cLean's Coal-bed lies closely upon the conglomerate, and is capped by a knoll or dome-shaped hill of sandstone.

---

* Many of the observations embodied in this description were made prior to the year 1845, but the text then prepared for publication has been recently re-written, with numerous corrections and additions, after a careful study of the whole ground, as lately as 1857.

The E. brow of Wray's Hill is begirt with cliffs of conglomeritic white sandstone from 30 to 50 feet in height. The floor of Well's Valley below is strewn with fragments of heavy conglomerate, the pebbles of which are as large as the egg of a goose. Although these blocks have doubtless come from some of the neighbouring summits, the rock from which they were derived was not found in place.

Returning now to the N. margin of the high land, we find six spurs projecting N. into Plank Cabin Valley. Each of these contains a shallow synclinal basin ranging S. into the Broad-Top plateau. A careful examination of these basins has led to the conclusion, that even the lowest coal-bed has been swept from all of them, except the second or that called Rocky Ridge, in which it has been preserved from denudation for half a mile to the N. of Savage's openings; but it certainly does not reach Trough Creek Gap, nor reappear on Shirley's Knob. Shirley's Knob is a monoclinal ridge of West-dipping rocks, belonging to a basin of which the W. side has been swept away. The highest stratum is a conglomerate, dipping 55° W. It therefore contains no coal. For a like reason no coal is thought to exist on the Round Knob, the Grave Mountain, the two W. spurs of the Broad Top, nor on the hill called Round Top.

The width of the synclinal basin of Rocky Ridge, from the E. to the W. outcrop of the sandstone stratum which supports the lowest coal-bed at Savage's old mines, is not more than 400 yards. The dip on the E. side of the basin is 60° N. 60° W. Opposite Taylor's mines, one and a half miles further S.W., the synclinal of the coal is broader, and the dips gentler, but the W. dip still remains the steeper of the two. A short distance N. of the Raven Rocks, where Rocky Ridge is broken off from the Broad-Top plateau, the breadth of the basin is about 300 yards; but the W. dip is almost horizontal, and the E. dip as steep as 50°. This change is owing to denudation, which has cut away the E. side of the basin nearly to its centre. The coal may be opened anywhere along the ridge on both outcrops, but is probably of impaired quality, except where the dips are at a high angle.

Savage's openings are adjacent to the W. summit of Rocky Ridge, about three-fourths of a mile S.W. of the gap occupied by Trough Creek. The coal at the mine dips sometimes S., though more frequently S. 25° E., at an average angle of 12° or 14°. It is about 4 feet thick, of excellent quality, and convertible into a good coke. Numerous obliquely transverse joints divide it into rhomboidal fragments. The seam is overlaid, and also supported, by solid layers of dark fine clay, each about six inches thick, which, by exposure, are converted into a plastic clay. Above the coal are 40 feet of dark slate, with a few bands of sandstone. A compact shale, used for whetstones, is also found, both above and below the coal. Soft yellow iron-ore, with layers of a hard chestnut brown variety, is found deposited around the Spa Spring near Savage's.

Taylor's openings are said to have yielded 4 feet of coal. Loose masses of a lean ore are found on the surface near by. The synclinal basin of Wray's Hill has a width, between the two summits, of 700 yards, from a point a little N. of Stambaugh's openings. The E. dips are 30°, and the W. dip 25° or more. Within this basin observations upon the Seral conglomerate lead to the inference that one, if not two, gentle anticlinal elevations exist. Coal-openings have been made across this shallow basin ; but the bed, although about 6 feet thick, has too light a covering of rock to be hard and good : it is undoubtedly the lowest bed of the series. M^{c}Lean's opening is said to have yielded 4 feet of light and very inflammable coal. The bed is divided by 3 inches of slate. Its outcrop is traceable all round the base of the knoll which rises from the barren plain, here more than a mile in breadth. The coal rests on slate, and its roof is sandstone. The platform of the Barrens seems to be a grey conglomerate, probably the upper bed of the Seral conglomerate.

A very gentle descent for two miles, from M^{c}Lean's, leads W. down into the valley of Trough Creek, and to Alloway's or Houck's old opening upon its W. bank, near the Fort Littleton Road. The coal, which dips 6° N. 60° E. averages 4 feet in thickness, one foot of which, in the middle is black slate. It is overlaid by slate. The bed contains more sulphuret of iron, and is more slaty, than that at Savage's, with which, and M^{c}Lean's, it is probably identical. The same fine-grained cherty-looking stratum, 3 feet thick, observed above Savage's coal, is seen above Alloway's Bed.

At the S. end of this basin, on the head-waters of Trough Creek, are Ludwig Fisher's openings upon a bed 2½ feet thick, capped by slate passing into sandstone 4 feet thick, above which, at the surface, is another coal-bed 2 feet thick. About one mile E. of this, and high on Wray's Hill, a coal has been opened by Mr Edwards. This bed is said to be 5 feet thick, including a band of slate 8 or 10 inches thick, 18 inches from the bottom. The dip is Westward.

For want of a detailed map we are unable to trace S., across the rolling plateau of the Broad Top, the anticlinal axis, with gentle dips, which separates the N. extremities of the Third and Fourth basins, or Round Knob and Grave Mountain ; nor can we follow the anticlinal that separates the Fifth and Sixth basins. Judging, however, from the gentle S.W. descent of the alternating strata at the head of Plank Cabin Valley, there would appear to be a general S.W. subsidence of the undulations towards the centre of the coal-field. The direction established for these and the main flexures of the region is S. 30° or 35° W.

In the N. portion of the plateau coal-openings are rare and unpromising.

The Umbral shale appears in the fields of H. Haupt. It outcrops around Grave Mountain. At Mr Diggens', fragments of Seral conglomerate appear ; and at H. Horton's, Coal-measures overlie the conglomerate. An imperfect opening revealed 2 feet of coal dipping 15° N. 60° W., 300 yards W. of which there are outcrops of hard grey and softer white sandstone, dipping 20° N. 60° W., and a little beyond this the dip is 10° S. 60° E., showing the middle line of the synclinal basin. From this to H. Millar's, the rocks undulate or lie horizontally, and but few exposures are to be seen. In this interval coal crops out at H. Haupt's. Mr Millar's fields contain olive and green shales ; and near his house there are fine exposures of massive Seral sandstone.

The bold bluff of massive white conglomeritic sandstone, from 10 to 15 feet high, W. of Millar's house, and dipping 10° S. 40° E., is probably the Seral conglomerate stratum. Below this occurs a lesser bluff of fine white sandstone, not so massive as the former. Scarcely 50 yards horizontally from the upper bluff a coal has been opened on a cleared slope, but it is only 6 inches thick at the opening.

An anticlinal flexure runs up the deep ravine between Mr H. Millar's and Corcillin's, on the W. side of which two coal-beds have been opened : the lowermost, with a poor covering, proved 2 or 3 feet thick. Above it is a bluff of Seral conglomerate, and 400 yards horizontally W. of it a higher coal 3 feet thick, but without proper cover or any breast for mining.

Passing farther to the S. we enter upon the ravine of Shoup's Run. This is a deeply-cut gorge, the general course of which traverses the coal strata, nearly at right angles, from the new village of Broad-Top City to the vicinity of Coalmont. It has afforded favourable opportunities for mining coal, and many mines are situated upon its borders. We shall detail the observations made upon these as they were followed up the stream from Coalmont E. towards Broad-Top City.

The first appearance of the Seral conglomerate, at the level of Shoup's Run, is about one-third of a mile above the village of Coalmont. Rising above the bed of the valley at an angle of 50° upon a S.E. dip, it forms, in Raven Hollow, which comes in from the S., a conspicuous ledge of rocks 20 feet high, representing the lower member. At this point the dip is about 45°, but the rock is intersected by numerous parallel joints, which almost obscure the less distinctly marked plane of bedding. These joints dip S. 75° E. at the high angle of 80°. The rock, when freshly broken, appears to be a pinkish-white very compact sandstone, weathering grey, and is not at all conglomeritic. A little above this ledge, and constituting the upper member of this Seral conglomerate, is a pure white fine-grained sandstone, which is exceedingly uniform in its bedding and splits into beautiful flags suitable for building purposes.

Within 100 feet of the Seral conglomerate on Shoup's Run, occurs Mr Schell's Opening upon the lowest coal. The dip of the bed at the mine-entrance is 20°, but it rises to 30° as the gangway advances S. The subdivisions of the coal are as follows:—

Coal, from 3 feet to 3 feet 10 inches; Slate, 5 inches; Coal, 5 inches; Slate, 1 foot; Coal, 1 foot 8 inches.

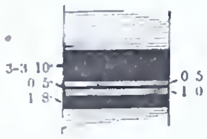


Fig. 315.—Schell's Coal.

This bed is known as Barnett's, from the old mine of Philip Barnett higher up the stream, and we shall hereafter designate this lowest workable seam by that title. Within 50 feet E. of Schell's Opening the coal basins and rises out to the surface upon a W. dip of 20° near the lowest house of the mining village. It then arches in a broad low anticlinal, and after forming a shallow basin again rises on a W. dip of 18° at the mines of the Broad-Top Railroad Company, leased to Mr A. Patrick. At these mines the coal has a total thickness of 4 feet 3 or 4 inches. On the N. side of the run, opposite Minersville, the same coal-bed is mined from four openings upon a breast which rises E., with several slight undulations, at an average angle of 15° or 18°, until it crops out on the flank of the great anticlinal which ranges across the valley between Minersville and Barnettstown. The latter mines are wrought by Powell & Saxton, as lessees of the Railroad Company. The Barnett Bed is the only one which has been opened on Shoup's Run in the general basin between the W. cropping of the Coal-measures and the anticlinal above mentioned.

This great anticlinal which crosses the run just W. of Barnettstown, and within a few hundred yards of the mines above alluded to, brings the lowermost beds of the Seral conglomerate to the water-level. It has the effect of throwing off the Coal-measures upon its flanks to form two lines of outcrop. The anticlinal ranging S. is believed to pass E. of Mr Osbourn's house and Horton's sawmill to cross Six-mile Run, and run through the hollow of Trough Spring Creek to Sandy Run, above its confluence with Long Run. On Shoup's Run the rocks at the anticlinal dip W. 20° and E. 25°.

The first mine upon the E. side of the axis is Patrick's Upper Mine, where the Barnett Coal is wrought. The coal itself is rather soft, and somewhat thinner than usual. Between this opening and the anticlinal there seems to be some disturbance in the strata, by which Patrick's Coal is sharply turned down from the outcrop to be again found near the Railroad level. The openings did not admit of examination, and we are ignorant of the true nature of the difficulty. The lower coal is quite faulty and worthless. On the opposite or E. side of the Run, which is here flowing N., occurs the mine of Messrs Orbison and Dorris, and near it is the old drift of Philip Barnett upon the same bed. The dip of the coal is quite gentle; its thickness is as follows :—

Coal, of excellent quality, 2 feet 10 inches ; Slate, from 3 to 5 inches ; Coal, 1 foot.

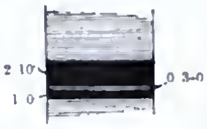


FIG. 316.—Orbison's (Barnett) Coal.

The bottom slate is pyritous and compact, the top rock is a compact olive shale, with interstratified layers of fine grey sandstone. The gangway upon the coal at the Orbison and Dorris Mine had penetrated 200 yards at the date of our visit (October 1857).

FIG. 317.—Philip Barnett's.

But a few hundred yards above this mine the coal basins at a depth of 45 feet beneath water-level. This was proved by a shaft sunk to coal, which was found dipping N.W. 3°. It was further proved by Mr Blair, who has driven a tunnel from the water-level to meet the coal as it rises to the surface. It was found about 100 yards from the point at which the tunnel entered. In these explorations a small seam of coal was encountered lying 10 feet above the Barnett Bed. On the hill-side opposite Blair's, and a little higher up the stream, is an old opening by Orbison and Dorris, on the same bed, dipping gently W.; and near the high trestling of the railroad is Noble's old drift mine. In the bed of the creek, and about 35 feet below the Barnett Bed, are seen two small seams of coal, separated by 4 feet of strata, and measuring respectively 4 and 6 inches. In the slates adjacent to these are found impressions of plants, and in the shales above thin bands of carbonate of iron. These thin coals lie close to the Seral conglomerate, which rises to the water-level, on a gentle anticlinal roll, about 150 yards farther E. This anticlinal has not been traced by us through the rugged country lying to the N. and S. of Shoup's Run, but it doubtless has an important influence upon the distribution of the strata.

We now enter upon a wide shallow basin, bounded on the W. by the anticlinal just mentioned, and on the E. by another ranging through the main plateau of the Broad Top at the head of the ravine of Shoup's Run, near Broad-Top City. As the conglomerate arches the former of these at the creek level, the Barnett Seam must soon re-enter the hills, but it has nowhere been opened. All the explorations hitherto made have been confined to the hill-sides, at some distance above the bed of the ravine, and they develop only higher coals. To these we shall now refer.

From three-fourths of a mile to a mile above or E. of the high trestling of the railroad, and a less distance from the anticlinal, are several openings upon two beds of coal, dipping E., usually separated by about 30 feet of strata, which occupy a position intermediate between the Barnett Bed and the next higher large bed, known as Cook's. The upper of these measures 3 feet, and is underlaid by bluish-grey argillaceous shale. The capping-rock is sandstone. The lower coal is 2 feet thick. At a higher level in the strata is the Cook Bed, wrought by the Broad-Top Improvement Company, at several points, upon a S.W. dip. At the lower mine three gangways enter the coal at different levels on the breast which inclines at an angle of about 3°; in one of these the following measurements were obtained :—

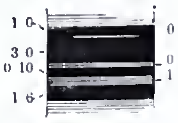


FIG. 318.- Broad - Top Improvement Company's Coal.

Coal, 1 foot; Slate, not always present, 1 inch; Coal, 3 feet; Slate, known as the mid-rock, 6 inches; Coal, 8 or 10 inches; Slate (average 6 inches), 1 foot; Coal, 1 foot 4 to 6 inches.

As the coal rises at a very gentle inclination, it is opened at several points near the Railroad, which ends at the upper mines of the Broad-Top Improvement Company, near the Old Cook opening, within half a mile of Broad-Top City. In these drifts great local variations are found in the thickness of the dividing-slates. In the mine of Messrs Keeley and Cunningham the lower slate has thickened to 4 feet, and the 16-inch band of coal is found beneath it. At another point where the coal is entered by a plane or breasting up the dip, the mid-rock or upper slate measures 15 inches. In one part of the Improvement Company's upper mine, the same slate is 3½ feet thick, but it does not average so much. In Jesse Cook's old mine, opposite the latter, the following are the subdivisions of the bed :—

Coal, 10 inches ; Slate, 3 inches ; Coal, 2 feet ; Slate, (upper member sometimes a sandstone), 1 foot 4 to 8 inches ; Coal, 5 inches ; Slate, 4 inches ; Coal, slaty and sulphurous, 1 foot 2 inches.

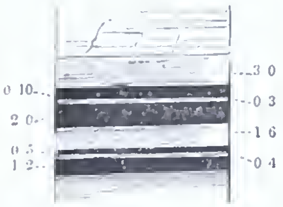


FIG. 319-320.—Cook's Coal.

The bed dips 6° S. 60° W. It is overlaid by 3 feet of slate which supports a dark-grey sandstone containing fossil impressions. There are indications of a thin band of coaly matter in these measures, 20 feet above the Cook Bed.

Near the road-side, and 200 yards S.E. of Jesse Cook's Mine, there is an opening upon a coal-bed, estimated to overlie the Cook Seam about 60 feet. It measures 3 feet, including a band of slate 1 inch thick, and 10 inches from the bottom. It occupies a position not far beneath the big sandstone stratum which supports the table-land of Broad-Top City. The same bed of coal occupying a corresponding position beneath the somewhat pebbly sandstone known as the "Big Rock," has been opened and drifted into upon the hill-side, a few hundred yards S.W. of the lower mines of the Broad-Top Improvement Company.

S. of the parallel of Shoup's Run, the Broad Top is intersected by other deep ravines, down which flow the waters of Six-mile Run, and the tributary branches of Castillo's Run, known as Sandy and Long Runs. At the extreme S.W. edge of the Broad Top is Kimber's Run, flowing into the Raystown Branch of the Juniata, 2 miles above Hopewell, at the mouth of Castillo's Run. In the interval between Shoup's and Six-mile runs, which flow at an average distance of 3½ or 4 miles from each other, rise the elevated summits of Barnett's Hill and Anderson's Knob. To the S. of the latter, and between it and Long's Run, lies Round Knob, and in range with it and Anderson's Knob occurs Swartz's Ridge, lying between Long and Sandy runs. This range of hills contains, on account of their structure and their height, the greatest residual thickness of Coal-measures. To the Westward the general plateau of the Broad Top exhibits a high irregularly undulating surface, which is quite covered with forest. As, however, the explorations for coal have been confined chiefly to favourable localities in the valleys below, and as the useful rock-exposures are few and isolated, the details of structure in this complicated district are still very obscure. As we lacked the invaluable guide of a good topographical map upon which to connect the exposures which exist, we were obliged to restrict ourselves principally to careful examinations in the transverse valleys, where we were aided by natural developments and the progress of mining.

On the Western slope of Barnett's Hill, upon the road from Coalmont to Fort Littleton, and a quarter of a mile from the former place, the Seral conglomerate or sandstone is exposed, dipping E. of S., at an angle of 15°. At a lower level Red shale crops out; and about 50 feet above the uppermost exposure of the sandstone, Mr Evans has opened the Barnett Coal-seam. The coal is much crushed, and is very irregular in thickness, varying from 4 feet to 6 feet, and even more. Its dip also is fluctuating both in direction and degree. Some distance higher on the hill, and more to the S., a bed apparently much higher in the series has been opened at various points in the vicinity of Mr Donaldson's house, upon the lands of Mr Schell. The gangways upon it were closed, and the thickness of the bed could not be measured; but this is said to be considerable. Farther S. a drift was entered upon a coal, which at the outcrop measured 1 foot, and contrary to expectation the coal dwindled away as the gangway advanced. In the shales beneath this coal, balls of white carbonate of iron, of good quality, are disseminated. Near the top of the hill, at Barnett's Sugar Camp, a fine bed of coal is opened. The bottom bench is 14 inches thick, the middle bench 2 feet 8 inches; the upper bench is not visible, but the thickness of the entire bed, including slates, cannot be less than 5 feet. The dip at all of these localities is gently E.S.E.

An old opening known as Hamilton's, and a more recent one, Entriken's, occupy positions at the base of the hill, near Hamilton's, on Put's Branch of Shoup's Run, within a mile of Coalmont. It is impossible, without further research, and the use of instruments, to define precisely the relative positions of the several coal-beds in Barnett's Hill. There is, however, sufficient evidence to enable us to affirm that the Coal-measures exist in great thickness, and that probably many of the valuable beds of the region will be found in it.

In describing the traverse of Six-mile Run, and the other streams flowing Westward from the Broad Top, it will be expedient, for the sake of clearness, to follow them Eastward from the river towards their sources. We come now to treat of the stratification and structure of the coal region as developed on *Six-mile Run.*

Where the ravine of Six-mile Run opens to the river-valley, the W. ridge of the Broad Top presents a curious projection to the river. This may, perhaps, be accounted for by a slight double roll in the flank of the mountain. The same may be seen at Hopewell and elsewhere, along the W. escarpment of the plateau.

For the first half-mile ascending the Six-mile Run the strata are composed of Umbral red shale, alternating towards the top with the sandy beds of the Seral rocks. The first exhibition of coal is that of the Lancaster Coal Company at the Old Riddle Mine. The locality of this mine is one of evident confusion in the strata, and much doubt yet remains about the identity of the bed with those occupying the same apparent horizon. The coal at the old drift dips gently W. into the basin where the new mine enters it. It was found at first to be 5 feet thick, but swelled to 10, and even 12 feet, as the gangway was driven forward. The roof is quite regular, but the floor very uneven. In the new gangway great difficulty in mining has arisen from an upheaval of the coal transversely to the centre of the basin. This occurred in the gangway, 100 yards from the mouth. The floor was found upheaved to the height of 15 or 20 feet, carrying coal and roof with it, but leaving a trace of the coal along the plane of dislocation. The dislocation extended entirely across the basin, and the impediments to mining, at the date of our visit, had not been overcome, though it was thought they soon would be. The coal is hard, often polished and crushed, and is divided by no regular stratum of slate, but is interleaved with thin plates of slate which adhere very tenaciously to it. The lower part of the bed is considered the best. The roof is a blackish olive slate with pencil fracture, 4 feet thick, becoming grey and more silicious upwards for 15 feet, and covered by hard, dark-grey laminated sandstone. Other massive, very hard, dark sandstones appear still higher in the series. Immediately beneath the coal there is a variable band of indurated fire-clay, containing balls of iron ore.

Thirty feet below the Riddle Coal appear beds of pale blue sandstone, weathering yellow and brown, from 6 to 12 inches thick, and perpendicularly jointed. They present a total thickness of 50 feet. Immediately beneath there is a crushed coal 2 feet thick, dipping E. at an inclination of 35°. Below this on the N. side of the gorge the Seral conglomerate is obscured by debris. On the S. side, upon the run, a mass of sandstone 20 feet thick rises from the water-level. This rock has all the characters of the Seral conglomerate of this region. It is a compact homogeneous heavily-bedded sandstone, traversed by parallel joints or cleavage-planes. The plane of bedding dips S. 80° E. at an angle of 45°. Beneath it appear nearly 150 feet of more flaggy sandstones, alternating in the lower part with red shale. Over it are visible 50 feet of blue argillaceous and sandy shales, including one or two thin bands of dark-blue slate; but no sign of the presence of coal can be detected.

If the massive sandstone really represents the upper stratum of the Seral conglomerate, we find it difficult to suppose that the 2-feet thick coal-bed above mentioned can represent a small seam usually found closely contiguous to the conglomerate, for the strike of the rock makes it appear fully 150 feet beneath that bed. The same difficulty forces us to regard the Riddle Coal as higher in the series than the Barnett Seam, to which it is generally regarded as equivalent. Any other supposition implies either an enormous thickening of the rocks between the latter bed and the conglomerate, or a transverse dislocation by which the strata on the N. side of the Run have been thrust E. several hundred feet.

Certain it is that the Riddle Coal-bed is, to all appearance, the lowest, with one exception, in the series. Some persons suppose a valuable bed to exist beneath it. Attempts were once made by Mr Hurl, of Huntingdon, to open such a bed upon the mountain, N. of Riddlesburg, and hardly 50 feet above the alternations of Seral and Umbral rocks. A bed 7 feet thick, it is commonly reported, was there discovered, dipping 40° S. 55° E. The floor is a greenish slate, underlaid by 3 feet of light-grey micaceous sandstone with coal impressions, reposing upon 10 feet of coarse grey ferruginous sandstone with quartz pebbles. Beneath this we find coarse granular light-grey hard sandstone 8 feet thick; fine-grained, greenish, thin-bedded sandstone 8 feet; interval 30 feet, and red shale surface debris downwards. Above the opening are seen slate and pebbly sandstone, overlaid by dark-grey sandstone. These exposures constitute a double line of cliffs along the mountain-side N.; the lower 30, the upper 25 feet high. A third ledge, 30 feet higher and near the summit, consists of rocks dipping 50° W., therefore forming with the latter a synclinal basin; but at the summit, rocks, which bear a close resemblance to those beneath the Riddle Bed, dip E. again. If these phenomena justify the opinion that a lower bed than any yet developed upon the Creek exists, and the true thickness be in any due proportion to its traditional size, it becomes important to discover it by careful research upon the Creek below the Riddle Mine.

The hill next E. of that which contains the outcrop of the coal-bed brings up the massive sandstone strata lying at the base of the Coal-measures upon a gentle anticlinal wave. The E. dip is 45°. These strata weather, in the upper portion, like the coarse and easily-disintegrated Meridian Sandstone of Warrior Ridge; the lower layers are harder and of a finer grain. The anticlinal has not been traced in its prolongation N. or S., though its magnitude would indicate it to be one of the leading flexures of the W. division of the Broad-Top. Ranging S. towards Sandy Run it ascends Thornhill Run, passing W. of Lowrie's and to the N. is found between J. Griffith's and Osbourn's.

At Brandon's Point, ascending the Run, sandstone strata, like those on the stream below the Riddle Mine, dip 20° E., and 100 yards further E. nearly horizontal strata of slate 10 feet thick border the Creek, from the bed of which coal was once taken at the point where a retaining-wall now supports the roadway. The stratum was said to measure 18 inches in thickness ; but upon reopening it, it was found to be 2 feet thick. It is overlaid by dark calcareous slate, abounding in fossil impressions. The slate descends gradually beneath the water and rises again as gently upon the E. side of the synclinal axis, outcropping in the bed of a lateral ravine which comes in from the S. about 30 feet above the flats. An opening has been made at an elevation of 60 feet above the outcrop of this slate, on the side ravine near Brandon's Point, and disclosed a coal smut 4 feet thick. This may be upon the outcrop of the Riddle Bed, as this seems to be its proper place. At the head of this ravine on the hill, 100 feet above the last-mentioned opening, a coal-bed has been entered by a drift for a short distance. The bed, including slates, measures 5 feet, of which from 3 to 4 feet is coal. The true place of these beds is still so involved in obscurity that it is impossible to define, with precision, their equivalents elsewhere.

The horizon of the Riddle Bed is obscured Eastward by undulations of the strata, and the few rock-exposures are unsatisfactory. The massive sandstones beneath that bed are nowhere seen as such above the water-level ; and the presumption is, the bed is for the most part below it.

An anticlinal axis may be remarked between Figard's Mill and Fairplay, crossing the ravine of Six-mile Run. It appears along the deep ravine E. of Mr Osbourn's house, and passes W. of Horton's Sawmill. Sandstone rocks appear on its E. slope, dipping 25° E. ; but on the W. we find slate, sandstone, and coal. The W. dip of 5° appears on the road from Osbourn's to Figard's Mill.

On the flank of this saddle a coal was struck in a well at Mr Osbourn's : it is 2 feet thick ; and on Mr Lynn's farm further W., and a fourth of a mile from the brow of the Broad-Top Mountain, a bed has been opened dipping 10° W., and yielding, at the outcrop, 3 feet of coal ; beneath the coal is shale 10 or 15 feet thick, and brown argillaceous sandstone. In the fields E. of Mr Lynn's house fragments of limestone appear. The rock has a grey ashy colour, smooth grain, and cherty aspect. The thickness of the bed has not been proved ; but its presence shows that we are high in the series of the Coal-measures. The anticlinal passing Osbourn's ranges S. through Trough Spring Hollow to Sandy Run.

A few hundred feet S.E. of Horton's Sawmill a massive ledge of sandstone rises upon a gentle W. dip. The rock is in all respects similar to that lying at the base of the Coal-measures.

On the S. side of the Ravine of Six-mile Run, just above the opening of Trough Spring Hollow, there is a ledge of coarse grey sandstone, known as the "Saltpetre Rocks," which dips 25° or 30° N., 60° W. Further E., 120 yards, are the "Thunderstruck Rocks," a hill-side exposure of blue and grey slates, and grey sandstone, geologically above the Saltpetre Rocks, and dipping 45° in the same direction. Between the two exposures, a bed of coal has been opened 30 feet above the Creek. The ledge of the Saltpetre Rocks may be followed S. 100 yards to its crossing of Trough Spring Creek. A short distance above, on the latter stream, the same rocks enter the ground upon a steep E. dip, and again form a basin, upon the gently-inclined W. side of which, a coal 28 inches thick has been opened. This coal has all the characters of the bed overlying that called the Cook Seam, at the head of Shoup's Run.

Returning now to Six-mile Run, we find, above the Thunderstruck Rock a few hundred yards, a curious wedge-like mass of coal, known as King's. At the surface of the hill-side the bottom of the coal has a gentle E. dip, and the top is very steeply inclined. Across the base of the wedge at the surface the bed is 15 feet thick, but it narrows down to about 5 feet at the point where the excavation terminated. Similar conditions, we are told, attended the outcrop of the coal opened between the Thunderstruck and Saltpetre rocks. In neither case did the mining penetrate far enough to develop the normal condition of the bed. The most natural explanation of the irregularity is surface action and hill-side pressure, though the coal itself is quite pure and solid. We are disposed to regard the King Coal as more nearly the equivalent of the Cook Bed than of any other. The rock found some distance above it resembles the "Big Rock" sandstone.

The whole neighbourhood of these natural and artificial developments is one of much obscurity and confusion. Systematic exploration is necessary to unfold its structure.

At Fairplay, one-third of a mile above the King's Coal opening, the dips are E., into a basin which passes about 100 yards E. of the tavern. 200 yards E. of the tavern is Richard Foster's old coal-opening upon the Creek side. The dip of the bed is gently E. This is owing to a slight roll of the strata dipping W. into the basin between the mine and Fairplay. The mine is now closed. The bed is said to be upwards of 3 feet thick. The roof is dark olive slate 4 feet thick, overlaid by the same thickness of pale-blue, apparently calcareous sandstone. The floor is of ash-coloured argillaceous shale 10 feet thick, containing a few nodules of iron ore, underlaid by 1 foot of blue sandstone, resting on 10 feet of black slate, which encloses two bands of nodular ore 2 or 3 inches thick.

On the S. side of the ravine, opposite Foster's Coal-bank, a shaft was sunk by Mr Richey upon a seam evidently higher in the series than Foster's, and apparently the Cook Bed. It rests upon olive shale, and is overlaid by sandstone. The coal, including a mid-rock slate, is 5 feet thick.

One-third of a mile above the shaft is the Old Lear opening, at the base of Round Knob. The following are the dimensions of the coal, which dips 3° W. :—

Coal, 1 foot 2 inches; Slate, 5 inches; Coal, 1 foot 9 inches; Slate, 2 inches; Coal, 2 feet.

The upper bench is the best; the lower is sulphurous and bony. It is thought to be the Cook Bed.

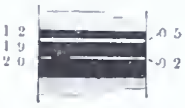


FIG. 321.—Lear Bed.

Above the Lear Coal-seam a stratum of limestone was found. It is a bluish black rock 3 feet thick, containing Septaria, or clay concretions, some of which are soft, others hard, with dark calcareous spar, or traversed by plates of opaque white spar. In it are found univalve and bivalve shells and corals.

About three-fourths of a mile above Fairplay, or Six-mile Run, a massive ledge of coarse sandstone displays itself, showing a very gentle N.W. dip, which is much obscured by innumerable cross-joints or cleavage-planes inclined E., but nearly perpendicularly. The ledge may be seen for some distance along the hill-side upon the N. On a branch of Six-mile Run, sometimes called Shreeve's Run, coming in from the S., at the E. base of Round Knob, and not more than half a mile from Six-mile Run, a rock identical in character, and unquestionably representing the Seral conglomerate, stands forth below Mr Cheyney's fields. The outcropping face of this rock forms a precipitous ledge 30 feet high, and the bedding inclines at a low angle (5°) N.W. under Round Knob. As is usual with this stratum, it is intersected by cross-joints dipping 85° S., 65° E. A few hundred yards higher on Shreeve's Run, and on the opposite side, the same rock enters with a very gentle E. dip into Shreeve's Hill or the S. prolongation of Anderson's Hill, which lies to the N. of Six-mile Run. The anticlinal ranges, therefore, through the ravine of Shreeve's Run, between the two exposures.

On the E. slope of Round Knob, back of the conglomerate cliff, in a field belonging to the John Griffith farm, now the property of English, Colwell, & Co., a drift enters upon a coal corresponding in position and character to the Cook Bed. Its subdivisions are as follows :—

Coal, 1 foot 6 inches (the bed lies nearly flat) ; Slate, 3 inches ; Coal, 1 foot 9 inches ; Slate, 8 inches ; Coal, 10 inches.

About 35 feet stratigraphically below this bed, another has been proved by shafting in another part of the same field. It is 3 feet thick. The shales over this coal contain numerous impressions of leaves and shells.

On the S.E. slope of Round Knob, overlooking the depression at the head-waters of Long Run, which flow S.W. into Sandy Run, a series of shafts, conducted by Messrs Richey & Foster, enable us to present the accompanying tolerably complete section of the Coal strata.

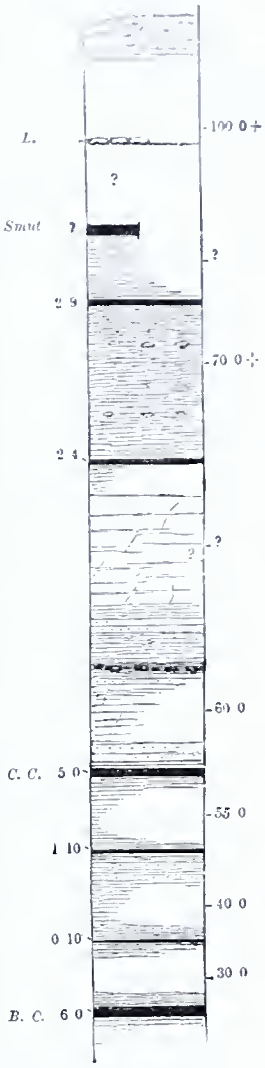


Fig. 322.—Strata in Round Knob.

1. The lowest opening is about 35 feet above the foot of the slope, bordering the gently deepening hollow. The bed of coal here proved is 6 feet thick, and is not divided by any slate-bands. The dip of the seam, in common with those on this side of Round Knob, is gently N. 40° W. into the hill.

2. Thirty feet above the coal, in the lower shaft, a bed was cut, measuring 10 inches, with a slate-roof.

3. Forty feet higher, a coal, 22 inches thick, of good quality, fracturing in rhomboidal blocks. Floor, a sandy shale ; roof, shale with impressions of leaves. This is doubtless the same seam as that met with on the E. side of the knob, as above mentioned.

4. Thirty-five feet higher, a coal 5 feet thick, including a band of slate 6 or 8 inches thick, 1 foot from the bottom. The upper slate of the Cook Bed, its equivalent, was not met with in this shaft, which, however, did not cut into solid coal.

5. Sixty feet above the last, a shaft penetrated 22 feet from the surface. At a depth of 5 feet, fire-clay was encountered : it proved 15 feet thick. The lower 5 feet contained many balls of argillaceous brown iron-ore. Below this, a black slate, 10 inches thick, presented itself, underlaid by sandstone. Above the shaft, a fine close-grained argillaceous sandstone, known as the "Whetstone Rock," outcrops upon the hill-side, and above it fragments of the "Big Rock" sandstone are visible in the more steeply-inclined slope, which its presence causes.

6. A coal 28 inches thick underlaid by sandy ferruginous shale. It corresponds in position to a coal-bed opened by a tunnel on Long Run, above the Hopewell Company's Mine, to which we may hereafter advert. Between this coal and that above it, a hill-side gutter exposes olive and dove-coloured shales, including a thin

bed of coal-slate, and several bands of fire-clay, containing nodules of brown ore. The dip of these measures is 12° N.W.

7. Seventy or more feet above the last-mentioned coal is a bed 33 inches thick, and free from slate.

8. Twenty-five feet higher, among olive shales, a thin smut of coal betrays the proximity of a seam which has not been opened. Above it are fragments of a loose-grained sandstone weathering deep red. We shall presently show that a similar rock overlies a large bed of coal, which occupies a position very high in the series on Long Run.

Above these indications of coal there are fully 100 feet of strata occupying the summit of the hill. They consist of shales capped by shelly sandstone. On the W. side of the synclinal of Round Knob, in E. Foster's fields, occurs an ash-coloured limestone stratum which should be found in this interval, though it there occupies a much lower level, which may be accounted for by the unsymmetrical denudation of the synclinal basin of the knob.

The range of the synclinal flexure, as observed from the elevated summit of Round Knob, carries it N. through Anderson's Knob and S. into Schwartz's Knob.

The first appearance of coal on Six-mile Run, E. of the bold sandstone exposure, is at Amos Figard's opening, which is one of the oldest in the region, having been made sixty years ago. The bed is 28 inches thick, and inclines gently E. It must, therefore, be upon the E. side of the Shreeve's Run Anticlinal, and cannot be many feet above the lower Seral sandstone.

One fourth of a mile further E. is the Old Loy and Patterson Mine, upon a coal lying at the N. base of Shreeve's Hill, and upon the E. side of a basin ranging through that hill. The dip is 5° W. The roof of the bed is a coarse sandstone, 5 feet thick, containing pebbles of milky quartz. The floor is of dark sandstone, full of vegetable impressions and layers of slate. The coal at the mine is 5 feet thick on the outcrop, but increases to 9 feet, and is 7 feet thick where the workings were abandoned. The opening was long since closed, but the coal is said to be free from slate, and of good quality. It occupies a position evidently low in the series, and is probably the equivalent of the Barnett Seam.

A fourth of a mile above this opening are sandstone bluffs, referable to the lower Seral conglomerate, dipping 5° W. Indications of coal were found on the road passing above these rocks. This is probably the outcrop of A. Figard's coal on the E. side of the basin. Three or four hundred yards higher up the creek, on the hill-side, slate and coal have been excavated, but the strata are not now visible in place. The dip is no doubt E.

We find no further positive developments of coal until we approach the Mountain House, upon the main plateau of the Broad-Top, at the head of Six-mile Run. Half a mile above the last locality of coal above alluded to, is Anderson's Mill, 150 yards E. of which we find the hill-side strewn with large masses of conglomerate rock, containing pebbles of nut and pea size. We are disposed to refer these fragments to the sometimes conglomeritic sandstone which overlies the Cook Bed. Near by, upon the road-side, at the base of the hill, Westward-dipping slates are exposed, supporting a coal-bed, whose presence is indicated by its smut. Between this point and the Mountain House we find no further exposures, if we except the olive sandy shales cut in places by the roadway ascending the hill.

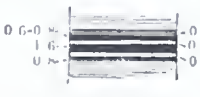


FIG 323.—Coal near "Mountain House."

N. of the Mountain House 150 yards a coal-bed has been opened for mining upon a dip of 12° or 15° N., 60° W. It presents the following divisions :—

Coal and slate, 6 inches ; Coal, 6 or 8 inches ; Slate, 3 or 4 inches ; Coal, columnar, 1 foot 6 inches ; Slate, 5 or 6 inches ; Coal, 8 inches.

This seam is denominated the "Spier Bed," and is generally regarded as overlying the Big rock sandstone, and consequently as superior in position to the Cook Bed. A second drift upon the same coal enters N.E. of the first opening. No change is perceptible in the bed, except an increased thickness of the upper dividing-slate, which measures 6 inches. Roof, blue, sandy, somewhat micaceous shale, 10 feet thickness exposed; dip as before. A short distance N. of the first mine, and at a somewhat lower level, a shaft was sunk from 30 to 40 feet, but cut no coal. It passed through shales to a bluish-grey variegated fine-grained sandstone.

On the cross-roads at the Bethel Church the dips are still W., but an anticlinal ranges through the high ground of the Hoover Place, E. of it. This throws E. dips into the valley of Trough Creek, on which, near the Fort Littleton road, and fully a mile from the Bethel Church, is the Old Houpt or Alloway Mine, alluded to in an earlier part of this Chapter.

The waters of Long Run, which take their rise from the high W. slopes of the Broad-Top to the S. of Shreeve's Hill and Round Knob, flow S. until they unite with Sandy Run, flowing more nearly W., to enter the river just above Hopewell. The lower part of the stream, outside of the Coal-measures, is usually denominated Castillo's Run. Observing the system hitherto adopted, we will ascend the deeply-cut ravines occupied by these waters.

Sandy Run, below its confluence with Long Run, a mile E. of the river, displays the coal strata more satisfactorily than they are developed on Six-mile Run.

Along the wide open valley of Castillo's Run the hill-sides expose red shale of the Umbral series, gently undulated by one or two axes of elevation. At the point of the hill entering the gorge of Sandy Run, about half a mile E. of the Machine Shop, a thorough cutting of the railroad exposes about 75 feet thickness of rocks beneath the Seral sandstone or conglomerate. The lower 40 feet comprise yellow and brown shales and sandstones, including near the bottom a thin band of carbonaceous slate. The upper 35 feet include 2 feet of blue ferruginous concretionary shale, some of which has been extracted as an iron ore; also a thin band of coaly matter, upon which repose rusty brown sandstones. Entering the cut from the W. the dips are Westerly, but roll over gently into E. dips, and are again lifted upon two abrupt, narrow anticlinal waves, descending finally beneath massive ledges of the Seral conglomerate. This latter rock flanks the point of the hill on the E., rising to a height of 100 feet above the stream. It is a white fine-grained sandstone in the lower part, becoming conglomeritic towards its upper limit. The thickness of two ledges comprising the stratum does not exceed 50 feet; dip, 40° S. 60° E.

Close beneath a third heavy ledge of sandstone, and not more than 20 feet above the Seral conglomerate, the lowest workable coal-seam is opened. The thickness of the bed is quite variable, ranging from 4 to 8 feet. It is comparatively free from slate, the only persistent band being 4 inches thick, and within a foot of the top.

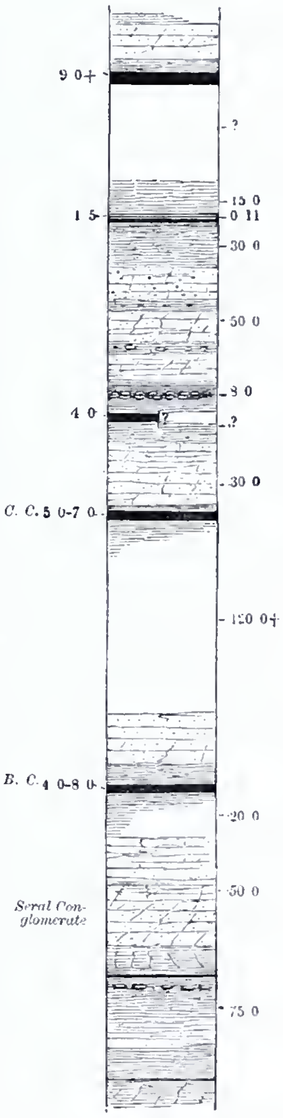


Fig. 324.—Sandy Run.

The second bed of coal opened on Sandy Run is that mined by the Hopewell Coal Company one-third of a mile further E. It is usually regarded as the Cook Bed, and is estimated to lie 120 feet higher in the series than the conglomerate coal. In the Company's mine it presents the following dimensions:—

Coal, 1 foot; Slate, 2 inches; Coal, with a thin Slate parting, 3 feet 2 inches; Coal and Slate, 1 foot 2 inches.

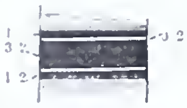


Fig. 325.—Hopewell Company's Coal.

In some places the total thickness is nearly 7 feet, but the bed at the mine is soft and crushed. The dip is 65° E. In working an air-hole up the breast the bed turned flat, and it crops out some distance back on the hill. It is overlaid by at least 30 feet of hard grey sandstone, and then by argillaceous fine-grained strata, suitable for whetstones. Slaty rocks succeed, and then a dark-blue, or black, very argillaceous limestone, in which no fossils could be found. This stratum is 8 feet thick; the lower part is ferriferous: above it a thin streak of coaly slate was found. Succeeding this is the "Big Rock," a stratum of massive white sandstone passing upward into a fine conglomerate; between the divisions are two beds of slate, the lower of which contains some nodules of iron ore. The entire thickness of the deposit is not less than 50 feet. Its position is 60 feet over the Hopewell Company's Coal-Bed, and therefore about 200 feet above the Seral conglomerate; dip, 75° E.

High on the hill above the Hopewell Mine, a gangway has been driven upon a coal-seam measuring from 3 to 4 feet in thickness, upon a very gentle E. dip. A line of shafts has followed the bed E. across a shallow basin, the W. dips of which are found to within a few feet of the East-dipping ledge of the Big Rock. It would appear to descend to water-level beneath that rock, and if so, should be found among the slates below the dark limestone stratum. If our identifications be correct, it corresponds in position to a bed opened above Jesse Cook's old mine on Shoup's Run, and to that proved above the Broad-Top Improvement Company's lower mines. On Round Knob it has not been opened.

The first coal-bed opened above the Big Rock is that to which Squire Horton drove a short tunnel on Long Run, just above its confluence with Sandy. The coal measures 17 inches in thickness, and is overlaid by 11 inches of coaly slate: dip, 65° S. 85° E. About 30 feet of slate and fire-clay intervene between it and the top of the "Big Rock." In the tunnel 15 feet of shale overlie the bed.

At the tunnel a brook coming in from the N. enters Long Run. About one-fourth of a mile up this stream, on its E. bank, an opening has been made upon a coal differing in aspect from those below. Its full thickness is not clearly shown, but seems to be, including slate, not far short of 9 feet. The coal is rough and somewhat slaty, but is said to burn well. The dip is 50° or 60° W. Indications of a large seam were seen on the W. side of the brook; no doubt the E. dip of the same. The two outcrops are not 100 yards apart. Resting upon the coal is a coarse dark-blue sandstone streaked with sparry quartz, and weathering dark brown or red. We have seen that fragments of a similar rock were found high on Round Knob. The coal is perhaps the highest workable seam in the region. The range of the synclinal is S. through Cheyney Knob.

On Sandy Run, 200 yards E. of the "Big Rock," appear the W. dips of the basin. Massive sandstone strata rise above water-level to descend again within 50 yards upon an E. dip of 70°. The E. dips of this sandstone may be seen on a little stream called Mine Run, flowing from the S. into Sandy Run, near the mouth of Long Run, about a fourth of a mile from the Hopewell Mine. The dip at this point does not exceed 30°, but close above the rock a coal is opened, dipping 75° or 80° E. The bed fluctuates in thickness from 3 to 5 feet, and is crushed and soft.

The sharp anticlinal flexure just referred to is supposed to be that which ranges across Six-mile Run, between Figard's Mill and Fairplay. On Sandy Run it is followed by a basin close upon the E. side, as the sandstones again appear upon a gentle W. dip.

From this point E. to the head of Sandy Run, a dense forest borders the stream and covers the adjoining slopes. Our data for displaying the structure of the region are limited. Good natural exposures are rare, and scarcely any excavations have been made. For a mile ascending the Run above the last neighbourhood, we find nothing to guide us ; we then have rocks perhaps lower in the series than the former, dipping 30° W. A fourth of a mile higher an anticlinal crosses the stream. The W. dips incline 60°, the E. from 50° to 60°. 40 feet of sandstone are here visible, overlaid by 30 feet of olive shale, and this, by a stratum of thin-bedded argillaceous bluff sandstone 1 foot thick. The axis must range to the W. of Schwartz's Ridge. Hence to the Chivington Mine is a distance of $1\frac{1}{4}$ miles without exposures.

The old Chivington Mine is situated upon the E. side of the basin of Schwartz's Ridge or Knob. The coal dips 7° W.N.W., steepening upon the rise E. 400 yards below the mine the dip is gently E. The thickness of the bed varies from 5 to 8 feet. The roof is a hard, heavy, dark-grey or black slate, weathering with a pencil fracture. No thick seams of slate traverse the coal, which is beautifully iridescent. About 6 feet over the main bed the presence of a small bed is indicated at the mouth of the drift. Within the mine, where the roof had fallen in, two such seams were found : they measure nearly a foot each, and are separated by 6 inches of slate. We are disposed to regard the Chivington Bed as very low in position, perhaps the lowest workable bed in the series.

The few exposures observed on Wray's Hill, E. of this opening, exhibited the rocks in a nearly horizontal posture. One bed of the coal has been opened by Mr Foster, $1\frac{1}{2}$ miles to E. It is said to be 6 feet thick, and horizontal.

One mile and a quarter N. of the Chivington Mine, on the side of Schwartz's Ridge, overlooking Long Run, a bed 5 feet thick is opened. Its position in the series is not determined.

At the extreme S.W. end of the Broad-Top, Kimber's Run enters the river. Hitherto this portion of the coal-field has attracted but little attention ; and, indeed, to the S. of the Run there seems small promise of finding any valuable beds of coal. Upon the Run, however, and to the N. of it, in Cheyney Knob, occur some matters of interest.

About one-third of a mile from the river a rapidly-sloping ravine or depression converges to Kimber's Run. Ascending this hollow, which heads to the N.E. at the Cheyney Ore-bank, we find the Seral conglomerate a little way above the Run. It is here a dense white sandstone, some beds of which are conglomeritic : dip, 30° S.E. A short distance above it, stratigraphically, coal has been turned out by the pick ; but the bed has not been regularly proved. Upon the hill-side bordering the depression upon the W., we find numerous exposures of slate dipping 80° E. : among these are indications of coal. Higher in the series, massive cliffs of sandstone stand out from the hill-side. The dip of the stratum is 85° E. In character it closely resembles the " Big Rock " over the Hopewell Company's mine on Sandy Run. Crossing the measures some hundreds of feet, we come to a coal-bed on the slope of Cheyney Knob, upon the E. side of the ravine. Coal has been dug from what appears to be a considerable seam, but the thickness of the bed is not known. Judging from the polished surfaces of the fragments, the coal is somewhat crushed and faulty. Associated with the bed are fragments of sandstone, weathering deep red, like that seen at the opening on a large coal in the basin E. of the Hopewell Mine. If it be the same stratum, Cheyney Knob must contain an unusual thickness of coal strata, for the dip at the shaft is still E., and the hill towers high.

Near the head of the hollow, not far from the Ore Bank, a band of limestone crops out; its thickness is not ascertained, but the band is important. The rock is a dove-coloured and light-blue very fine-grained limestone, weathering ochreous yellow. It rests among olive shales, and is said to burn to a bluish-white strong lime.

The Cheyney ore-deposit is on the very top of the hill, between Sandy Run and Kimber's Run. The excavation was at one time extensive, and the ore, which is of the argillaceous brown variety, was found in irregular streaks, imbedded in sandy clay. The mine was long since abandoned, but whether for want of ore, or because of deterioration in quality, we are unable to say.

The first appearance of coal on Kimber's Run is in the bed of the stream, half a mile from the river. The bed is crushed and impure; including a thin slate-parting, it is one foot thick. It is overlaid by dense blue sandstone, and rests upon hard blue argillaceous sandstone and slate. Dip, 52° S. 67° E.; strike, N. 23° E.

Two hundred feet higher up the creek, and forty feet geologically above the small bed, two seams have been opened. They are each 18 inches thick, and separated by 6 feet of blue slate; they are overlaid by 2 feet of blue slate, supporting blue sandstone. Dip, 55° S., 67° E. There have been found on the hill-side above this opening indications of a higher bed.

Two hundred yards up the creek may be seen the centre of the basin. The E. dips are as high as 80°, the W. do not exceed 20°. Of the East-dipping strata 20 feet of slate are visible in the bed of the stream, overlaid by whetstone and slate, 35 feet thick, to the change of dip. At this point a thick mass of slate descends by a gentle curve W. to meet slate, dipping almost perpendicularly at the level of the stream. The measures here exposed resemble closely those described as overlying the Hopewell Company's bed on Sandy Run. There appears, however, at this point, a greatly increased thickness of slate. If the horizon be the same, this great development of slate may arise from a dislocation in the centre of the basin, by which slates which dip steeply beneath the water-level are again upraised to their present elevation above the stream.

Loose masses of ferriferous black limestone are found in the run at the basin. On the hill-side, sandstone overlies the slate.

Just below the forks of Kimber's Run, and 200 yards E. of the last locality, openings have been made into coal, but they are now closed, and do not admit of examination. The coal lies 30 feet beneath a cliff of coarse, blue, flaggy sandstone, weathering brown and yellow, and dipping N. 70°, W. 35°. The bed is said to be 4 feet thick. Below it a heavy bedded sandstone rises gently E., and flanks the hills on both sides of the ravine. No indications of coal are found ascending the run, and the gently undulating rise of the sandstone, which we think is the Seral conglomerate, precludes the hope of finding any.

Iron Ores.—In the preceding pages of description we have incidentally referred to those localities where iron ore has been found imbedded in the strata; but in no instance have developments been made which could lead us to infer the presence of any very valuable band in any part of the Broad-Top Coal-field. This is particularly true of the characteristic arch of the Coal-measures, the argillaceous carbonate of iron. Perhaps the most favourable specimens of this variety were met with in the excavation of the race of Figard's Old Mill, on Six-mile Run, where a bed measuring 12 inches was found. Of the argillaceous brown ores few localities exist, besides the Cheyney pits, before described; but surface specimens of a very good quality are quite abundant on Josiah Horton's land, N. of the road from Fairplay to Broad-Top City, one mile from the former place. Scattered fragments are also found on E. Lynn's place (formerly Thomas Griffith's); but excavations for the benefit of the Hopewell Furnace, many years ago, led to no encouraging results.

AREAS OF THE COAL-BASINS OF PENNSYLVANIA.

I cannot more appropriately close this elaborate account of the several coal-fields of the mountain-chain of the State than by presenting a summary statement of their several areas in square miles. As various and very discordant estimates of the dimensions of the Anthracite Basins have already been published, I deem it proper to mention that the following have been derived from a careful equation and measurement of their areas as these are represented in the Map of the Coal-fields which accompanies this work; and as this Map is the result of exact instrumental surveys, it is not probable that the areas given can deviate far from the actual superfices of the Coal-measures. For comparison, the Bituminous and Semi-bituminous Coal-fields are also given.

		Square Miles.
Anthracite Coal-fields,	Southern or Pottsville,	122.52
	Eastern Middle,	28.45
	Western Middle,	81.53
	Wyoming or Northern,	177.43
		409.93
Semi-bituminous Coal-field,	Broad-Top Mountain,	23.80
Bituminous Coal-fields,	All the Coal-measures N.W. of the Alleghany Mountain, with the N. end of the Cumberland Basin in Bedford,	12222.04
	Total in Pennsylvania,	12655.77

BOOK IX.

NINTH PALÆOZOIC DISTRICT, OR BITUMINOUS COAL-FIELDS AND THEIR ASSOCIATED OLDER CARBONIFEROUS STRATA.

DIVISION I.

VESPERTINE AND UMBRAL SERIES IN THE BITUMINOUS COAL REGION OF PENNSYLVANIA.

TOPOGRAPHICAL RELATIONS OF THE VESPERTINE AND UMBRAL SERIES.

It has been shown that in the Anthracite region the several coal-basins are encircled by a continuous belt of the Vespertine rocks, the conglomerate of this series constituting a second or outer barrier to each coal-field. In like manner the whole Bituminous coal region, and each subdivision or basin, is enclosed by a girdle of the same formation. A marked difference, however, prevails in the topographical features connected with the Vespertine outcrops in the two districts : in that of the Anthracite a deep valley intervening between the Seral and Vespertine ridges, being scooped out of the soft Umbral Red Shale in virtue of its great thickness and high angle of dip ; while in the Bituminous region only a gentle depression, the consequence of much-reduced dimensions and comparative horizontality, divides the outcrops of the two harder formations. By the great diminution in the thickness of the Red Shales, the Vespertine conglomerate is brought nearer to the true coal-rocks, and forms with the Seral conglomerate but one general elevated rim or border to the several basins. The deep erosion of the softer underlying argillaceous formations, the Ponent and Vergent rocks, has left these harder and more resisting strata relatively high, forming the margins of the synclinal plateaus of the Coal-measures. In tracing the boundaries of the several coal-fields in the introduction to Book VIII., we have been, in fact, delineating the extensive outcrop of the whole of the associated Vespertine and Umbral series, and therefore any further description of this sort seems altogether unnecessary. The reader, in tracing the course of the several belts of these, to which the map and sections will prove his surest and easiest guide, has merely to bear in mind, that the outer edge of the Vespertine series, formed by the base of the Conglomerate, usually occupies a position in the escarpment of the Alleghany Mountain, and the other elevated plateaus of the coal, about midway between the base and summit ; all the lower slopes being formed by the Ponent strata. The upper margin of the series coincident with the top of the Umbral Red Shale, follows the inner edge of the depression I have alluded to, separating the Vespertine from the Seral conglomerate. This latter formation generally capping the highest summits or crests of these table-lands, the Umbral Red Shales occupy in such cases a sort of elevated terrace or shoulder on the mountains, a little below their actual tops. In those great anticlinal belts, such as Laurel Hill and Chestnut Ridge, where the denuding waters have not penetrated to the Ponent and Vergent strata, the Vespertine rocks occupy the higher flanks, and even the summits, of the mountains which sustain the Seral conglomerate and the Coal-measures at a subordinate elevation on their slopes.

CHAPTER I.

VESPERTINE CONGLOMERATE.—GEOGRAPHICAL DISTRIBUTION.

THE geographical range of the Vespertine sandstone seems to be coextensive, at least in the region of Pennsylvania and Ohio, with that of the great Bituminous coal-basin. It not only forms the S.E. border of the coal throughout the entire length of the main escarpment of the Alleghany Mountain in Pennsylvania, but skirts it on its N.W. side, extending the whole way into Ohio. Along its outcrop in the Alleghany Mountain, it is everywhere separated from the Seral conglomerate and sandstones by a considerable thickness of the Umbral Red Shale; but this latter formation thinning out upon the N. border of the coal region in its course towards the W., the more widely spread Vespertine sandstone becomes the immediate floor of the Seral series. This coalition takes place by the final exhaustion of the Red Shale near the head-waters of the Sinnemahoning. By a similar disappearance of all the rocks of the Ponent series in the same direction, the Vespertine sandstone comes into contact, on the other hand, with the Vergent strata; and this contact occurs in the same region, or near the middle part of the N. boundary of the Bituminous coal district. The near resemblance in lithological composition of the Vespertine strata, here exhibiting the type of a very argillaceous group, and the Vergent rocks, renders their recognition in the field of their common boundary not a little uncertain; especially as there is a great scarcity of definitive fossils in the Vergent series, until we penetrate to some depth within its upper strata. Thus limited by the Seral rocks above and the Vergent beds beneath, the Vespertine sandstone skirts the coal region from the head-waters of the Clarion westward, and forms in part the N.W. boundary of the Great Basin, the whole distance to the Ohio River, and even into Kentucky.

MODIFICATIONS IN THE TYPE AND THICKNESS OF THE VESPERTINE SANDSTONE IN THE BITUMINOUS COAL REGION.

In the escarpment or S.E. front of the Alleghany Mountain of Pennsylvania, the Vespertine sandstone, no longer possessing the coarseness of a conglomerate, is an argillo-silicious group of strata, consisting of white, grey, and yellowish sandstones, with interstratified beds of dark shale and slate. Some of the shales resemble very closely in colour and composition those of the true Coal-measures, and they embrace occasional layers of dark carbonaceous slate, not unlike that which covers many coal-seams. They are generally destitute, however, of the characteristic vegetable fossils, and nowhere present us with beds of genuine coal. In this S.E. belt, or that of the Alleghany Mountain, the general thickness of the formation is between 800 and 900 feet. Thus in the bold hills on Pine Creek, between the main stream and the first fork—that is to say, about 5 or 6 miles N.W. of the front of the Alleghany Mountain—the strata measure 850 feet. On the Old Portage Railroad, along the front of the great escarpment, the whole formation is of rather less dimensions, being not more than 750 feet in total thickness, including certain strata that form a passage between it and the underlying Ponent rocks.

This portion of the Vespertine series, in extending N.W., loses more and more its distinctive arenaceous character. We have seen already, that in the interval between the more N.W. belts, in the Anthracite region, and the Alleghany Mountain, the nearest outcrop of the Bituminous Coal-basins, it undergoes so marked a reduction in the size of its particles as to be no longer entitled to the name of conglomerate; and we now observe in advancing across these latter basins, that this general modification in the character of the stratum continues, the sandstone becoming more and more argillaceous and fine-grained, and the shales and slates augmenting in relative abundance. Accompanying these changes, there is a progressive and very perceptible declension in the thickness of the stratum in the same direction. Thus, at Ralston, which is in the second basin from the Alleghany Mountain, the formation, as now limited by us, consisting of grey and brownish flaggy argillaceous sandstone, some shales, and a little argillo-carbonaceous sandstone, presents a total thickness not exceeding 475 feet; and around the Towanda Coal-field, which is further N., but in the same general belt, it measures from 600 to 650 feet. Tracing it still further to the N.W., we find its thickness diminishing progressively, and at the N.E. end of the sixth or last basin, namely, in M^cKean County, in the vicinity of Smethport, it is reduced to less than 200 feet. From this district S.W., through Warren and Crawford counties, this formation changes its dimensions and its aspect much more slowly, inasmuch as in this part of its outcrop it is receding less rapidly from its S.E. margin, where it possesses its greatest development. Starting from the S.E. part of the S.E. outcrop, and comparing it as it reappears in the successive anticlinals which uplift it in Somerset and Westmoreland, we perceive it to undergo, in that quarter likewise, the same diminution of mass and reduction in coarseness from S.E. to N.W. In Laurel Hill, at the gorge of the Conemaugh, its thickness probably does not exceed 650 feet, whereas upon the Portage Railroad it is not less than 750 feet.

CHAPTER II.

UMBRAL RED SHALE.—GEOGRAPHICAL DISTRIBUTION.

This formation, which possesses so remarkable an expansion in the Anthracite district, having a thickness at its maximum of at least 3000 feet, undergoes, like the Ponent deposits, which it much resembles in composition, a very rapid abatement of its bulk as it ranges N.W., and, like that group, altogether ceases to be traceable before we reach the sources of the Sinnemahoning. It exhibits a continuous but thin outcrop along the whole line of the Alleghany Mountain; but even in that belt it is of very subordinate importance to the Vespertine sandstone. Though it does not spread far W. along the N. border of the Great Bituminous Coal region, there can be little doubt of its wide expansion in that direction, under the coal-rocks of the S. side of the slate, as will presently appear when we compare the dimensions of the stratum as seen in its various outcrops.

W. & A.K. Johnston, Edinburgh

LAUREL HILL AND PLAIN OF WESTERN PENNA

MODIFICATIONS IN THE TYPE AND THICKNESS OF THE UMBRAL RED SHALE IN THE BITUMINOUS COAL REGION.

The very uniform character which this formation retains throughout the Anthracite region, gives place to one a little more diversified in the Bituminous Coal region. We have already seen, that in the most N.W. outcrops of the former district—those near the Wyoming Basin—it begins to lose the monotonous composition of a simple red shale, and to acquire a somewhat new type by the introduction of grey and greenish shales, and grey argillaceous sandstones. In that portion of the Bituminous Coal region which lies opposite to the Anthracite district, this Umbral series exhibits, in even a higher degree, this character of an alternating group. It consists usually of two or more strata of soft red and variously-coloured shales, separated by a thick interposed body of grey flaggy sandstone. Throughout all this northern district there is the same general deficiency of calcareous matter which is visible in the red shale surrounding the Anthracite basins. There is, however, a very much greater proportion of the ferruginous ingredient. It has been already shown, in the description of the Lackawanna Coal-field, that the Umbral shales even there contain, near their contact with the Seral conglomerate, a considerable quantity of iron ore, in the form of a rather crude silicious protocarbonate of iron. This ore is perceptibly more abundant, richer, and less silicious, in the part of the Bituminous Coal region now under consideration.

Tracing the formation S.W., along the E. escarpment of the Alleghany Mountain, and in the several anticlinals to the W. of this, in Somerset, Westmoreland, and Fayette counties, it gradually assumes a type more removed from that of the Anthracite region. The chief portion of the mass consists of the characteristic soft red clay-shale; but it includes a larger portion of blue, greenish, and yellowish shale or marl, and a less amount of intercalated sandstone than belongs to the stratum further N. It contains also a less abundant share of iron ore; but the feature which specially distinguishes it in this district is its calcareous matter, the quantity of which, gradually augmenting, becomes very conspicuous, under the form of a distinct limestone stratum, as we approach the S. side of the State. The limestone shows itself near the base of the formation, appearing in the more E. outcrops, namely, near the Broad-Top Basin, and in Somerset County, in the form of a very thin but continuous stratum, enlarging gradually but regularly in its extension W. and S.W., until, upon the confines of Pennsylvania and Virginia, it assumes the magnitude of an important sub-formation. In this thin calcareous member of the Umbral series of our State, we may recognise the nearly vanished marginal portion of one of the thickest and most extensive of all the Appalachian strata of the States to the S.W. and W. of us. It is nothing else than the nearly exhausted edge of the great Carboniferous or Umbral limestone of Virginia, Tennessee, Alabama, Kentucky, Indiana, Illinois, Missouri, and regions still more remote, in many of which districts this rock is the principal or only Umbral formation.

Details.—Let us now examine more in detail the features of this interesting Umbral Red Shale as they appear in some of the different localities where it has been studied. Proceeding as usual S.W., the district which first demands our attention is that of Bradford, Lycoming, and Clinton counties.

In the First Coal Basin, or that of the Alleghany Mountain, the formation possesses the composition shown in the following sections derived from localities near the West Branch of the Susquehanna.

On Lick Run, near Farrandsville, we meet with the following alternations of Red Shale and Grey Sandstone: Ascending (see Fig. 326), first, above the true Vespertine Sandstone, which here contains a few thin courses of scattered white pebbles, is a bed of soft Red Shale, about 65 feet thick, and containing two bands of nodular iron-ore. To this succeeds a stratum of Grey Sandstone, very analogous in aspect to the underlying Vespertine Sandstone; this is not less than 250 feet in thickness. Upon this there lies another Red Shale, measuring, as nearly as could be ascertained, 30 feet. Above this Upper Red Shale commences the true Coal-formation, here introduced by a mass of flaggy white sandstone, the true character of the Seral Conglomerate not appearing. One of the layers of iron ore in the Red Shale is 6 inches thick; the other, 20 feet higher, is 10 inches. The quality is good, but the quantity insufficient.

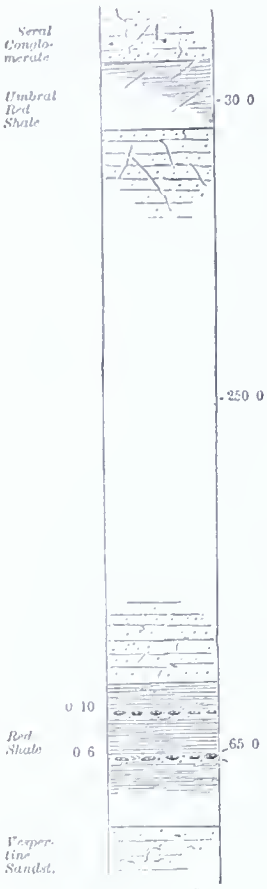


FIG. 326.—Lick Run.

On *Queen's Run*, which is a few miles E. of the previous locality, the condition of things is essentially the same. Here the upper bed of Red Shale is 25 feet thick, and the dividing sandstone 230 feet. The Upper Red Shale contains the two layers of iron ore seen at Lick Run: they are separated by variegated Red and Yellow Clay-shale.

In the Second Coal-basin the formation exhibits, at Ralston on Lycoming Creek, where only a part of it is visible, very nearly the same type, being composed of two beds of Red Shale, and an intermediate stratum of Grey Sandstone. The principal differences are in the less degree of thickness of this sandstone, and in the position of the iron ore which here occurs near the top of the Upper Red Shale, and not, as near Farrandsville, in the Lower.

The section of the strata on Red Run, about three miles from Ralston (see Fig. 327), displays the following rocks of the Umbral series, in the descending order:—

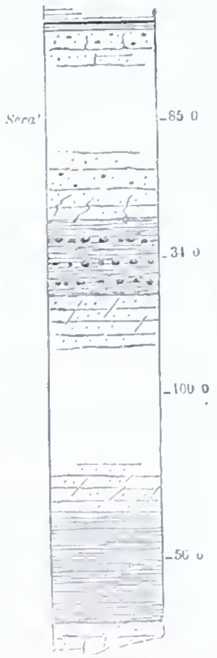


FIG. 327.—Red Run, Ralston.

1. Blue and Red mottled Clay-Shale, containing much excellent Carbonate of Iron in nodules, 14 feet; 2. Grey Sandstone, 100 feet; 3. Red Shale, 50 feet.

The iron ore is imbedded in a mottled shale immediately under the Seral conglomerate. The layer of shale in which it is imbedded is in all about 6 feet thick, and the ore constitutes perhaps one-half of the bulk of the mass. It will be mentioned again in the chapter on the Coal Rocks of this Second Basin.

In the Third Coal-basin, at Blossburg, and farther S.W., the Umbral Red Shale presents the same triple character. The iron ore characteristic of the Upper Bed of Red Shale is here met with imbedded in olive-coloured shale, immediately beneath the Seral conglomerate. Some of this ore possesses a curious oolitic structure: it will be spoken of again in the chapter treating of the Coal Formation at Blossburg; and its chemical composition may hereafter be furnished in the Table of Analyses.

When we advance to the Fourth Basin, or that North of Wellsborough, we lose all traces of the formation, except a thin deposit of the Red Iron Ore imbedded in a narrow layer of shale. The horizon of this iron ore, which is externally discoverable by the ochreous springs, and accumulation of Bog Ore issuing from it, is discernible even in the First Basin, and also on the Cowanesque, and in the vicinity of Coudersport. It is a good guide to the boundary which separates the Vespertine Sandstone from the Seral conglomerate.

Transferring our attention now from the country N.E. and N. of the Susquehanna to the region of the Conemaugh, we find this upper Umbral formation to undergo a great increase of thickness, and to change materially in some of its features. In the Alleghany Mountain, on the Portage Railroad, it consists of two portions, a thick stratum of red shale, measuring 370 feet, and a bed of very arenaceous limestone under this, which measures 30 feet. Between this limestone and the great Vespertine sandstone only a very thin stratum of the red shale here intervenes. The limestone is characterised by the great distinctness of the oblique planes of deposition of its more sandy layers. These meet each other at various angles in separate unconformable groups. No independent thick mass of grey sandstone, such as enters into the formation in the region of the Susquehanna, is to be met with in this more Southern district.

Crossing the Coal-basins N.W., we find the Umbral red shale exposed on the Conemaugh, near the viaduct of the Portage Railroad, and again in the anticlinals of Chestnut Ridge and Laurel Hill.

The following table represents the strata as they exhibit themselves in descending order on the Pennsylvania Railroad, S.E. side of Laurel Hill, Conemaugh Gap :—

Umbral.—Seral coarse grey sandstone, from 50 to 60 feet; grey argillaceous sandstone, 8 feet; white sandy shale (with grey oolitic ore, from 6 to 12 inches) 6 or 8 feet; white argillaceous sandstone and sandy clay with irregular beds of ore shale, 30 feet; white ore in ferruginous shale, 3 feet; sandy shale, 2 feet; red shale, visible, 25 feet; interval, red shale (?) 150 feet; red shale, 50 feet; white argillaceous sandstone, 20 feet; light blue sandy limestone, including 1 foot of red shale, 50 feet.

Vespertine.—Grey calcareous sandstone, &c. 400 + feet.

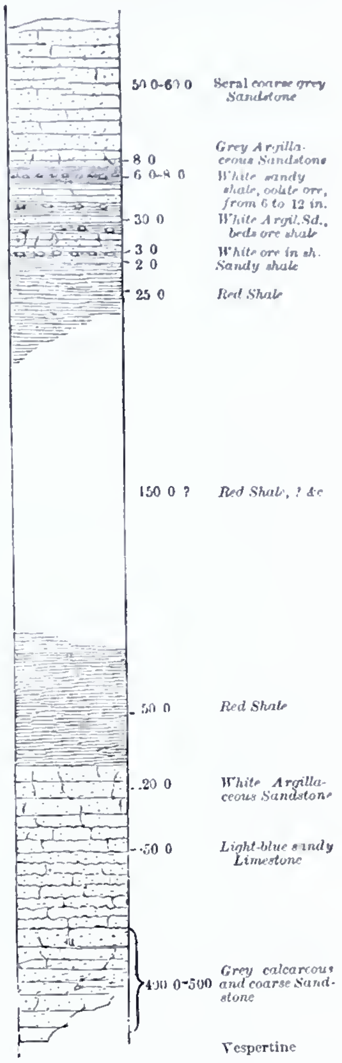

50 0-60 0
Seral coarse grey Sandstone
8 0
Grey Argillaceous Sandstone
6 0-8 0
White sandy shale, oolite ore, from 6 to 12 in.
30 0
White Argil. Sd., beds ore shale
3 0
White ore in sh.
2 0
Sandy shale
25 0
Red Shale
150 0 ?
Red Shale, ? &c
50 0
Red Shale
20 0
White Argillaceous Sandstone
50 0
Light-blue sandy Limestone
400 0-500
Grey calcareous and coarse Sandstone
Vespertine

Fig. 328.—S.E. side of Laurel Hill, Conemaugh Gap.

In the following section, which is appended for comparison, the top of the formation is not clearly recognised, yet there is an obvious reduction of thickness of the mass. Umbral strata visible on N. side of Conemaugh River, at Conemaugh Furnace, N.W. side of Laurel Hill :—

Seral, loose, coarse, and fine pebbly sandstone —— (?); red and green marl alternating, red predominant, including a few thin sandy layers, 35 feet; grey fine-grained sandstone, 5 or 6 feet; impure white ore, from 1 to 3 inches; alternating red and green shale, bands of sandstone, including 6 inches coarse ore, 17 feet; argillaceous sandstone, 3 feet; red shale and green argillaceous sandstone, 3 feet; red shale, cutting out coarse grey sandstone, 10 feet; red and green shales and argillaceous sandy beds, 8 feet; calcareous sandstone, 10 to 12 feet; red sandy limestone, 3 feet; light bluish-grey sandy limestone, thick-bedded and very oblique, 40 feet; Vespertine sandstone, coarse grey and obliquely bedded, several hundred feet visible on N. side of river.

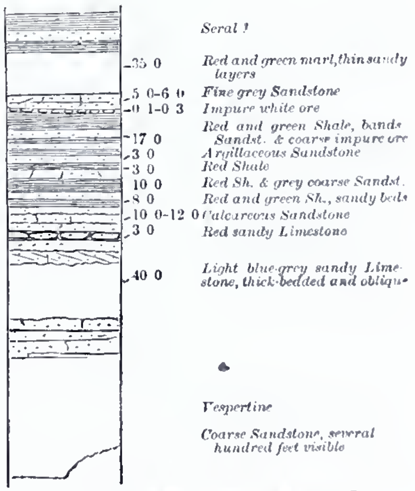

Seral ?
35 0
Red and green marl, thin sandy layers
5 0-6 0
Fine grey Sandstone
0 1-0 3
Impure white ore
17 0
Red and green Shale, bands Sandst. & coarse impure ore
3 0
Argillaceous Sandstone
3 0
Red Shale
10 0
Red Sh. & grey coarse Sandst.
8 0
Red and green Sh., sandy beds
10 0-12 0
Calcareous Sandstone
3 0
Red sandy Limestone
40 0
Light blue-grey sandy Limestone, thick-bedded and oblique
Vespertine
Coarse Sandstone, several hundred feet visible

Fig. 329.—N.W. side of Laurel Hill, Conemaugh Furnace.

The strata are well exposed on the Pennsylvania Railroad in the W. half of Chestnut Ridge Gap, as follows :—

Seral (?)—*Coal*, 1 foot; green shale and iron ore, 75 feet; argillaceous sandstone and shale, 45 to 50 feet; shale, 15 feet; *Coal*, 2 feet 4 inches; calcareous shale and fire-clay, 10 feet.

UMBRAL, 195 feet.—Interval, red shale (?) 25 feet; red marl or shale, 50 feet; grey sandstone, 5 feet; red marls, 20 feet; sandy limestone, 40 feet; olive shale, faint vegetable impressions, 55 feet.

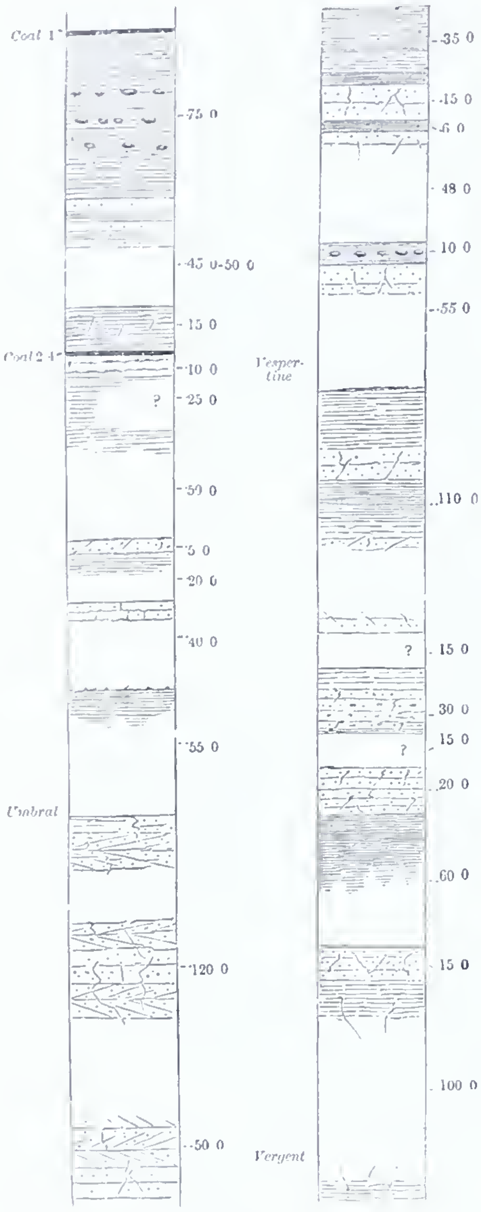


FIG. 330.—Section of Strata exposed on Pennsylvania Railroad, in western half of Chestnut Ridge Gap.

VESPERTINE, 339 feet.—White coarse quartzose sandstone, with diagonal bedding, containing vegetable remains, 120 feet; light grey sandstone, obliquely bedded, weathering brown, 50 feet; alternation; blue sandy shales, and green and purplish marls, 35 feet; light blue massive sandstone, 15 feet; greenish and blue marl, 6 feet; light-grey micaceous and argillaceous sandstone, including 2 feet of calcareous breccia 8 feet from bottom, 48 feet; dark ferruginous shales, iron-ore balls, 10 feet; light-grey fine micaceous sandstone, massive, some shaly beds, vegetable remains, 55 feet.

VERGENT, 365 + feet.—Olive shales, thick-bedded argillaceous fine-grained sandstone, dark-olive shales and flaggy sandstone, with small carbonised stems, fucoids, 110 feet; interval, 15 feet; olive shales, layers of fucoidal grey argillaceous sandstone, some of them containing small pebbles, 30 feet; interval, 15 feet; thin-bedded fine-grained light-grey sandstone, with scolithus and fucoids, 20 feet; dark olive and blue shales, 60 feet; fine-grained greenish micaceous sandstone, 15 feet to railroad level at fault, 10 feet upthrow on E side; olive shales, some layers fossiliferous, 100 feet to river-level, loose lump containing fish scales (?)

In extending W., the Umbral limestone grows gradually less sandy, and one division of it becomes charged with characteristic fossils such as Producta and other forms, distinctive of this part of the carboniferous period. In the Chestnut Ridge, as our section shows, the upper part of the formation is composed of variegated shales, red, green, blue, and even black. Some of these are carbonaceous, and distinct seams of coal are met with in them in more than one locality, showing that even previous to the production of the Seral conglomerate, there had arisen that curious union of circumstances which resulted in the formation of this inestimable gift of nature.

At Cool Spring Furnace we find two beds of coal, each about one foot thick, imbedded in these shales beneath the conglomerate. Under the coal-bearing portion of the shale there occurs a bed of blue protocarbonate of iron, in three layers of irregular nodules, some of which have a diameter of several inches.

It is not probable that any large deposits of coal will be found in the stratum of shale, inasmuch as the Seral conglomerate appears, with some exceptions in the N.W. counties, to underlie the lowermost workable coal-bed in all the coal-basins in our State; but as a depository of ore, it merits close investigation. This stratum is well exposed on the Loyalhanna near Youngstown: here its beds are red and blue, well laminated and compact, and dip 10° nearly due W. The thickness, from approximate measurements, must be 90 feet.

The Umbral limestone can be traced from the Conemaugh to the S. side of the State, along each of the main anticlinals. Throughout this region it is a more or less silicious limestone, or a limestone containing a small quantity of pure and well-rounded grains of sand, and it is of fine texture, and of a light-blue colour, though sometimes its tint is yellowish-green. On the national road it is found on the first ridge, and also on the main mountain; in the former case dipping

W. 15° N., at an angle of 25°. It lies in layers of from 1 to 10 feet or more in thickness, separated by bands of calcareous shale. The upper part is remarkably full of fossils, as is also the intervening shale. On the Loyalhanna there are two beds or layers exposed, separated by a thick bed of red and yellow shale, containing a few bands of limestone. The lower bed is a most singular rock, of a light-blue colour, and very hard; it breaks with a semi-conchoidal fracture: it dips nearly due W., at an angle of 10°. Occasionally the yellow colour predominates, giving the rock the exact appearance of some varieties of serpentine. When exposed to water it decomposes, the calcareous matter being washed away, leaving a porous and silicious crust of an inch or two in thickness, which will not effervesce. This bed measures 30 feet in thickness, being a nearly solid rock, without a seam. The upper rock is of a darker colour, harder and more fossiliferous, and 4 feet in thickness. At other points on Chestnut Ridge, this rock is met with having a considerable thickness, but no opportunity was there afforded for accurately measuring it.

On the Conemaugh, this stratum is exposed on both sides of the axis, dipping both E. and W. There is reason to believe that small quantities of lead and zinc ore may be detected in the lower beds of this deposit, particularly on Chestnut Ridge, where it seems to have reached its greatest development. Regarding it and the accompanying red and variegated shales as belonging to the Umbral formation, underlying the W. Coal-measures, the whole group will be seen to be much thicker here than further North-eastward, especially along the Alleghany Mountain, while its features are more characteristic. The dark-blue bed of limestone, which is full of fossils, usually affords an excellent lime.

On the Youghiogheny, about a mile above its falls, both beds of the limestone, the fossiliferous and arenaceous, are well exposed, and have a thickness of 30 feet. The underlying Vespertine sandstone is well seen along Sherman's Run. Beneath the clearly-defined outcrop of the massive Seral rocks, loose pieces of the iron ore peculiar to this position are seen in the upper part of the red shale.

The Vespertine and Umbral series nowhere reappear in the S. part of the Bituminous Coal region W. of the great anticlinal of Chestnut Ridge. The reader will find a detailed description of this interesting division of our Appalachian Rocks, under their more Southern type, in the reports upon the Geological Survey of the State of Virginia. In a preceding part of the present work we have detailed the special characters which the series displays in the synclinal basin of Trough Creek Valley, bordering the Broad-Top Coal-field.

DIVISION II.

GENERAL VIEW OF THE BITUMINOUS COAL STRATA.

INTRODUCTORY CHAPTER.

STRATIGRAPHICAL ARRANGEMENT OF THE COAL-MEASURES OF WESTERN PENNSYLVANIA.

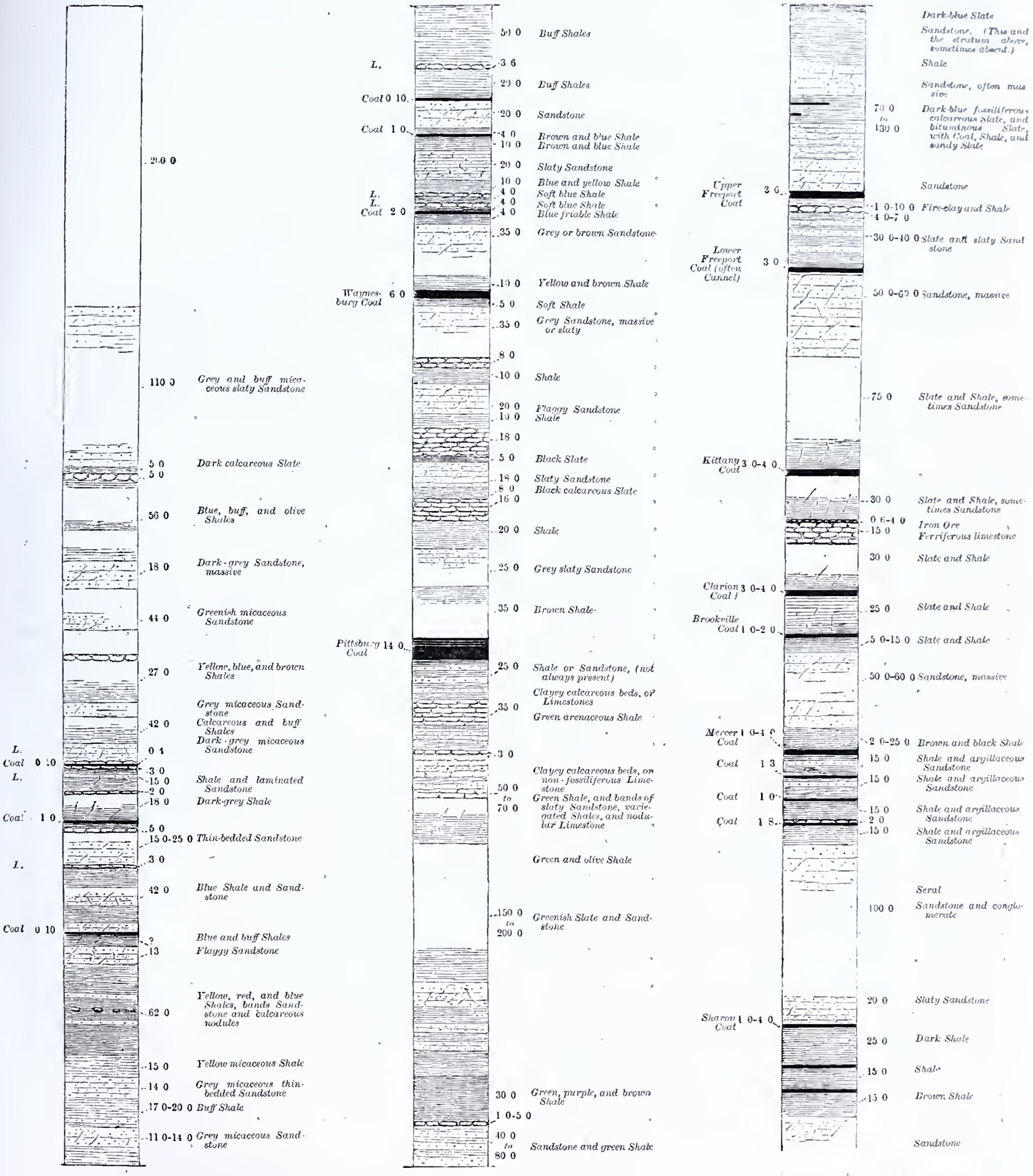
Under the general view of the Seral series or Coal strata, I have already described (see Introduction to Book VIII.) the composition of the Bituminous Coal-measures of Western Pennsylvania, and classified them under the five groups into which they are naturally divisible; but a further more minute subdivision is called for in this place, to enable the reader to follow readily the detailed account of the coal-beds and other individual strata to be treated of in the following chapters.

The annexed analysis of the Western Coal-measures is not offered as an exhibition of their type universally throughout the basin, for that would be to assume, contrary to what has been already stated, that every member of the series is continuous and unvarying throughout this wide field. It should ever be remembered that no one locality, nor any one district even, of sedimentary deposits, can strictly represent the sediments of an area greatly more extensive than its own limits; nor can we select a given neighbourhood as a type of the whole, but merely as a specimen of perhaps its most varied features and contents. It is in this latter sense merely that the column here appended is offered as an illustration of the general contents of the basin. It is purposely compiled from observations carefully made over the extensive belt of country lying between the Alleghany and Monongahela rivers and the Western boundary of the State. Its subdivisions are therefore to be viewed as by far more correct for that district than for the country to the E. of it; and the further we withdraw from it, the less and less applicable will it prove as a guide. And furthermore, it must be borne in mind that the dimensions and features here assigned to the strata are not retained by them throughout the long belt of country from whence this synoptic view has been derived, but are only vouched for as belonging to them in the neighbourhoods whence they get their names.

A GENERAL VERTICAL SECTION OF THE BITUMINOUS COAL STRATA OF PENNSYLVANIA, WEST OF THE ALLEGHANY AND MONONGAHELA RIVERS, COMPILED FROM NUMEROUS LOCAL SECTIONS, EMBRACING THE BELT OF COUNTRY FROM MERCER TO GREEN COUNTIES.

	Feet.	In.
Blank,	200	0
Grey and buff micaceous slaty sandstone,	110	0
Dark calcareous slate,	5	0
Limestone,	5	0
Blue, buff, and olive shale,	56	0
Dark-grey massive sandstone,	18	0
Greenish micaceous sandstone,	44	0
Limestone, thin.		

	Feet.	In.		Feet.	In.
Yellow, blue, and brown shale,	27	0	*Limestone,*	0	4
Grey micaceous sandstone, Calcareous and buff shales, Dark-grey micaceous sandstone,	42	0	Coal,	0	10
			Limestone,	3	0
			Shale and laminated sandstone,	15	0



200 0
110 0 Grey and buff micaceous slaty Sandstone
5 0 Dark calcareous Slate
5 0
56 0 Blue, buff, and olive Shales
18 0 Dark-grey Sandstone, massive
44 0 Greenish micaceous Sandstone
27 0 Yellow, blue, and brown Shales
Grey micaceous Sandstone
42 0 Calcareous and buff Shales
Dark-grey micaceous Sandstone
L. 0 4
Coal 0 10
L. 3 0
15 0 Shale and laminated Sandstone
2 0
18 0 Dark-grey Shale
Coal 1 0
5 0
15 0-25 0 Thin-bedded Sandstone
L. 3 0
42 0 Blue Shale and Sandstone
Coal 0 10
? Blue and buff Shales
13 Flaggy Sandstone
62 0 Yellow, red, and blue Shales, bands Sandstone and calcareous nodules
15 0 Yellow micaceous Shale
14 0 Grey micaceous thin-bedded Sandstone
17 0-20 0 Buff Shale
11 0-14 0 Grey micaceous Sandstone
50 0 Buff Shales
L. 3 6
20 0 Buff Shales
Coal 0 10
20 0 Sandstone
Coal 1 0
4 0 Brown and blue Shale
10 0 Brown and blue Shale
20 0 Slaty Sandstone
10 0 Blue and yellow Shale
L. 4 0 Soft blue Shale
L. 4 0 Soft blue Shale
Coal 2 0 4 0 Blue friable Shale
35 0 Grey or brown Sandstone
10 0 Yellow and brown Shale
Waynesburg Coal 6 0
5 0 Soft Shale
35 0 Grey Sandstone, massive or slaty
8 0
10 0 Shale
20 0 Flaggy Sandstone
10 0 Shale
18 0
5 0 Black Slate
18 0 Slaty Sandstone
8 0 Black calcareous Slate
16 0
20 0 Shale
25 0 Grey slaty Sandstone
35 0 Brown Shale
Pittsburg Coal 14 0
25 0 Shale or Sandstone, (not always present)
Clayey calcareous beds, or Limestones
35 0 Green arenaceous Shale
3 0
Clayey calcareous beds, or non-fossiliferous Limestone
50 0 to 70 0 Green Shale, and bands of slaty Sandstone, variegated Shales, and nodular Limestone
Green and olive Shale
150 0 to 200 0 Greenish Slate and Sandstone
30 0 Green, purple, and brown Shale
1 0-5 0
40 0 to 80 0 Sandstone and green Shale
Dark-blue Slate
Sandstone. (This and the stratum above, sometimes absent.)
Shale
Sandstone, often massive
70 0 to 130 0 Dark-blue fossiliferous calcareous Slate, and bituminous Slate, with Coal, Shale, and sandy Slate
Sandstone
Upper Freeport Coal 3 6
1 0-10 0 Fire-clay and Shale
4 0-7 0
30 0-40 0 Slate and slaty Sandstone
Lower Freeport Coal (often Cannel) 3 0
50 0-60 0 Sandstone, massive
75 0 Slate and Shale, sometimes Sandstone
Kittany Coal 3 0-4 0
30 0 Slate and Shale, sometimes Sandstone
0 6-4 0 Iron Ore
15 0 Ferriferous limestone
30 0 Slate and Shale
Clarion Coal 3 0-4 0
25 0 Slate and Shale
Brookville Coal 1 0-2 0
5 0-15 0 Slate and Shale
50 0-60 0 Sandstone, massive
Mercer Coal 1 0-4 0
2 0-25 0 Brown and black Shale
15 0 Shale and argillaceous Sandstone
Coal 1 3
15 0 Shale and argillaceous Sandstone
Coal 1 0
15 0 Shale and argillaceous Sandstone
Coal 1 8
2 0
15 0 Shale and argillaceous Sandstone
Seral
100 0 Sandstone and conglomerate
20 0 Slaty Sandstone
Sharon Coal 1 0-4 0
25 0 Dark Shale
15 0 Shale
15 0 Brown Shale
Sandstone

Fig. 331.—A general vertical section of the Bituminous Coal Strata of Pennsylvania, W. of the Alleghany and Monongahela Rivers, compiled from numerous local sections, embracing the belt of country from Mercer to Green counties.

	Feet.	In.
Limestone,	2	0
Dark-grey shale,	18	0
Coal,	1	0
Shale and limestone,	10	0
Thin-bedded sandstone,	15—25	0
Limestone,	3	0
Blue shale and sandstone,	42	0
Coal,	0	10
Blue and buff shale, thin.		
Flaggy sandstone,	13	0
Yellow, red, and blue shales; bands of sandstone and calcareous nodules,	62	0
Yellow micaceous shale,	15	0
Grey micaceous thin-bedded sandstone,	14	0
Buff shale,	17—20	0
Grey micaceous sandstone,	11—14	0
Buff shale,	50	0
Limestone,	3	6
Buff shale,	20	0
Coal,	0	10
Sandstone,	20	0
Brown and blue shale,	4	0
Coal,	1	0
Brown and blue shale,	10	0
Slaty sandstone,	20	0
Blue and yellow shale,	10	0
Limestone,	4	0
Soft blue shale,	4	0
Limestone,	4	0
Soft blue shale,	3	0
Coal,	2	0
Blue friable shale,	7	0
Grey and brown sandstone,	35	0
Yellow and brown shale,	10	0
Waynesburg Coal,	6	0
Soft shale,	5	0
Grey sandstone, massive or slaty,	35	0
Limestone,	8	0
Shale,	10	0
Flaggy sandstone,	20	0
Shale,	10	0
Limestone,	18	0
Black slate,	5	0
Slaty sandstone,	18	0
Black calcareous slate,	8	0
Limestone,	16	0
Shale,	20	0
Grey slaty sandstone,	25	0
Brown shale,	35	0
Pittsburg Coal,	14	0

	Feet.	In.
Shale or sandstone, not always present,	25	0
Clay, clayey calcareous beds or limestones,	35	0
Green arenaceous shale,		
Limestone,	3	0
Clay, calcareous beds, or non-fossiliferous limestone,	50—70	0
Green shale, and bands of slaty sandstone,		
Variegated shales and nodular limestone,		
Green and olive shale,	150—200	0
Greenish slate and sandstone,		
Green, purple, and brown shale,	30	0
Limestone,	1—5	0
Sandstone and green shale,	40—80	0
Dark-blue slate, } sometimes absent,		
Sandstone,		
Shale,	70—130	0
Sandstone, (often massive),		
Dark-blue fossiliferous calcareous slate, and bituminous slate with coal, when of notable dimensions, called the Elk Lick Coal,		
Shale, sandy slate, and sandstone,		
Upper Freeport Coal,	3—6	0
Fireclay and shale,	1—10	0
Limestone,	4—7	0
Slate and slaty sandstone,	30—40	0
Lower Freeport Coal (often Cannel),	3	0
Freeport sandstone, massive,	50—60	0
Slate and shale, sometimes sandstone,	75	0
Kittanning Coal,	3—4	0
Slate and shale (sometimes sandstone),	30	0
Iron Ore,	4 in. to 6	0
Ferriferous limestone,	15	0
Slate and shale	30	0
Clarion Coal,	3—4	0
Slate and shale,	25	0
Brookville Coal,	1—2	0
Slate and shale,	5—15	0
Tionesta sandstone (massive),	50—60	0
Brown and black shale,	2—25	0
Tionesta or Mercer Coal,	1—4	0
Shale and argillaceous sandstone,	15	0
Upper Porter Coal,	1	3
Shale and argillaceous sandstone,	15	0
Middle Porter Coal,	1	0
Shale and argillaceous sandstone,	15	0
Mercer limestone,	2	0
Lower Porter Coal,	1	8
Shale and argillaceous sandstone,	15	0
Seral sandstone and conglomerate,	100	0

	Feet.	In.
Slaty sandstone,	20	0
SHARON COAL,	1—4	0
Dark shale,	25	0
COAL,	?	
Shale,	15	0
COAL,	?	
Brown shale,	15	0
Sandstone,		

This extensive series of rocks, omitting the more subordinate beds of coal, sandstone, and shale, admits of being classified in accordance with the following scheme, which represents the subdivisions that have been adopted in picturing the Coal-measures upon the Geological Map of the State. The tabular arrangement, besides presenting the names employed in this work for the several strata, and the natural groups into which we have thrown them, exhibits the average thicknesses of these groups in the districts where they are best developed.

			Feet.
4.	Upper Barren Measures,		1200
	Waynesburg Group, and Pittsburg Coal and Limestone,		
3.	Lower barren Measures,	Unproductive rocks, mostly slates and shales, and containing green and black limestone bands,	400—500
	Mahoning massive bed of sandstone,		50— 75
	The Freeport Group,	Elk Lick Coal,	100—250
		Upper Freeport Coal,	
		Freeport Limestone,	
		Lower Freeport Coal,	
	Freeport, or contorted Sandstone,		15—50
2.	Clarion Group,	Kittanning Coal,	100—200
		Ferriferous Coal, wanting at the West,	
		Ferriferous Limestone,	
		Clarion Coal,	
		Brookville Coal,	
	Tionesta Sandstone,		60
	Tionesta Group,	Mahoning Limestone,	10—100
		Tionesta Coal,	
		Upper and Middle Porter Coal,	
		Mercer Limestone,	
		Lower Porter Coal,	
1.	The Seral conglomerate, embracing locally the Sharon Coal Group as a member,		50—100

GENERAL DESCRIPTION OF THE SEVERAL BITUMINOUS COAL BASINS.

To acquire a clear conception of the singular manner in which the coal strata of the bituminous region of Pennsylvania are distributed, let us, with a Geological map before us, imagine ourselves stationed at a commanding height above the surface, somewhere in the central part of the great W. basin ; say at Pittsburg. To the S. and W. there spreads an immense undulating plain, composed entirely of the Coal-measures, stretching far into Virginia, Kentucky, and Ohio. From our point of view the whole area to the S. and W. boundaries of the State to the base of Chestnut Ridge on the E., and to a line through Mercer and Franklin counties on the N., is occupied exclusively by this formation. Let us now direct our observation to the tracts which border this deep principal basin.

To the S.E. we discern a succession of long, narrow, parallel troughs, which have their general S.E. limit in the crest of the Alleghany Mountain. These are either entirely or partially insulated from the main W. basin, and also from each other, by the bold, parallel, and anticlinal ranges of Chestnut Ridge, Laurel Hill, and Negro Mountain, and their prolongations N.

Towards the N.E. the running-out of the main W. basin, and of these subordinate troughs which lie to the E. of Chestnut Ridge, is marked by some interesting features of symmetry, the clear recognition of which will materially assist us in tracing the scattered patches of the coal-rocks, by which the general mass is flanked in that direction; for, gazing from our supposed height upon the whole sloping table-land descending from the crest or escarpment of the Alleghany Mountain, to the Monongahela and Alleghany Rivers, we perceive that between these limits this broad plain is traversed in a N.E. and S.W. direction by a remarkable group of strikingly parallel and equidistant anticlinal elevations of the strata, which constitute on its S.E. side the conspicuous mountain-ranges just enumerated; and N.W. of Chestnut Ridge a succession of lower axes that continue to undulate the strata, but soon cease towards the S. to control the topography.

The accompanying general section (See Pennsylvania Central Railroad Section) of the coal-field from the Ohio River at Pittsburg, by the line of the Pennsylvania Railroad, to the summit of the Alleghany Mountain, exhibits distinctly the relative magnitudes and positions of six of the eight axes or great flexures of the strata. The *First* arch to the W. of the summit of the Alleghany Mountain upon this line of section, is in the high belt of hills which crosses the Conemaugh near the Railroad Viaduct; the *Second* coincides with the broad and massive mountain called Laurel Hill; the *Third* forms the somewhat less elevated Chestnut Ridge; the *Fourth*, a much flatter one, crosses between Beatty's Station and George's Summit; the *Fifth*, crossing the Conemaugh about 3 miles E. of Saltzburg, passes a little E. of Grapeville; the *Sixth* is a broad double undulation, one wave ranging E. of Stewart's, the other occurring at Turtle Creek (this latter developed as the principal one on the Kiskiminetas above Warren); the *Seventh* about 2 miles W. of Leechburg on the Kiskiminetas, but not appreciable on the line of our section; while yet another, the *Eighth* and last, which is parallel to all the rest, crosses the Alleghany between the mouths of the Mahoning and Red Bank creeks.—(See also Section, No. IX. of the Map.)

These great anticlinal waves of the strata prolong themselves many miles from the line of section towards the N.E. But five of them, as the map will show, are more persistent than the rest, not only extending to the Sinnemahoning and the N. Branch of the Susquehanna, but crossing those streams and controlling the whole topography still further E. and N., even beyond the New York line and the valley of the N. Branch of the Susquehanna. By these five larger axes the whole region of the Bituminous Coal has received its marked division into six separate basins, in one or two of which the other lesser axes have their more limited range; and to these the name of sub-axes will be given in the description of the region.

The influence of all these flexures upon the distribution of the coal strata, the uppermost of the formations, is very striking. By bringing to the surface lower rocks than those belonging to the Seral series, the axes of Chestnut Ridge, Laurel Hill, and the other conspicuous mountain-belts, have insulated, as we have said, the coal-rocks of the E. portion of the whole region from the rest, and thrown them into several narrow troughs. On the contrary, the axes, to the W. of Chestnut Ridge, elevate no inferior formation to the day, in the district near the Conemaugh, for the Coal-measures constitute the lowest rocks exposed by them. They, nevertheless, throw the coal-fields, which they traverse, into subordinate troughs or basins, insulating the upper beds, and permitting the lower only to arch from one basin over into the next, as do those of Chestnut Ridge and Laurel Hill in their N.E. prolongation, where they have so subsided as to carry the strata beneath the Coal-measures out of sight.

The result of this peculiar structure (anticlinal axes and included basins) upon the distribution of the coal strata, as we trace them N.E. from the region of the Conemaugh, is simply this : the anticlinals and synclinals rising in that direction, with the general upward slope of all the strata towards New York, the basins grow progressively shallower, as respects the depth or thickness of their contained coal-rocks, and consequently the higher beds successively disappear along the middle lines of the basins, leaving only the lower ones remaining, while the lower beds are also successively denuded from the anticlinal uplifts, allowing the still lower formations to appear. These, by their emergence along the axes, invade the once continuous coal-formation, and part it into a number of strictly isolated basins.

These, which of course are but extensions N.E. of the several troughs in ranging forward separated from each other, contain less and less of the Coal-measures, both superficially and in thickness, until at last the formation ceases to be continuous, being prolonged only by a few scattered patches occupying the highest knobs of the long and narrow synclinal table-lands in which these basins terminate. Leaping, as it were, from summit to summit, these detached masses of the coal formation lead us, but often by long skips, to within a few miles of the North Branch of the Susquehanna on the E. and the New York line on the N. With these and the intervening anticlinal lines as guides, we may, in imagination, readily restore the positions of the once ample coal-basins, which overspread all the N. side of Pennsylvania. If we embrace the whole of this coal region N.W. of the Alleghany Mountain under one general survey, it presents considerable analogy in the distribution of the coal-rocks to the form of the human hand—the wide Western Basin standing for the palm, the separate continuations of the minor basins springing from this being like the fingers ; while the intervening anticlinal tracts, destitute of coal, represent the interdigital spaces. The above explanation will be rendered more intelligible by a reference to the N.W. portions of the General Sections IX., VIII., VII., VI., and IV. of the Map.

The Anticlinal Axes and their intervening Coal-basins.—To acquire a more minute knowledge of the actual distribution of the coal-rocks, it is necessary to take first a rapid survey of the principal basins or troughs and the anticlinal belts which separate them. In this sketch we shall proceed, as usual, from the S.E. to the N.W., tracing each individual trough and axis S.W. as far as it will carry us. We shall begin, therefore, in Wyoming, Bradford, and Tioga counties, the quarter where the several bituminous coal-basins reach their E. termination ; but for convenience sake, and for reasons that will hereafter appear, we shall describe all the region lying N.E. of the Conemaugh, separately from that which lies to the S.W. of it.

SUBDIVISION I.

BITUMINOUS COAL-BASINS NORTH OF THE CONEMAUGH AND OHIO.

CHAPTER I.

First Basin and Principal Axis N.W. of the Alleghany Mountain.—This is a long and narrow synclinal table-land, known in Wyoming and Sullivan counties as part of the Mahoopeny Mountain; and in Lycoming, Clinton, and Centre counties, as the summit of the Alleghany Mountain. Its S.E. boundary in the former counties is determined by an axis, not numbered with the five great axes of the Bituminous Coal region, because, crossing the North Branch of the Susquehanna above the mouth of Tunkhannock Creek, it simply penetrates a S. extension of the Great Plateau, and issues from it again W. along the valley of Muncy Creek, being practically, when the whole topography of this part of the State is viewed on a grand scale, little else than the N.E. prolongation of the great axis of Bald Eagle Mountain and Nippenose and Nittany valleys. Where this axis penetrates the Alleghany Plateau, this seems to have no true coal-basin. To the S. of it the table-land of the North and Bowman's Mountain is overspread by grey Vespertine Sandstone.

The Mahoopeny table-land, on the contrary, though principally occupied by the same formation, embraces in its higher tracts a few isolated shallow patches of the Seral conglomerate and Coal-measures. The positions of these will be defined, after we have traced the basin in its prolongation S.W. (See General Section IV.)

For the rest of its length to Cambria County, the high synclinal belt containing the first range of Coal-measures is bounded by the S.E. escarpment of the Alleghany Mountain. The N. or N.W. limit of its trough is very well defined by the belt of older formations lifted to the surface on that side in a long gently-bending anticlinal axis, the central line of which passes the North Branch of the Susquehanna, near the Wyalusing Falls, and the West Branch above Rattlesnake Run.

From the North Branch of the Susquehanna, nearly to the waters of Lycoming Creek, the rocks exposed along this anticlinal belt are the upper members of the Vergent Series and the Ponent strata; from Lycoming Creek, on to the West Branch, they consist chiefly of the Vespertine Sandstone; from the vicinity of the West Branch to the Moshannon, the only formation on the surface arching the anticlinal line is the Seral conglomerate.

About 3 miles S.W. of the Moshannon, the tract of conglomerate tapers to a point, and the Coal-measures themselves, in their lower members, there saddle the arch, and cause the two basins—before divided as coal-basins—to coalesce as a continuous field. From this point S. the axis grows rapidly less conspicuous, so that its prolongation, even across Clearfield Creek, is somewhat questionable, while there can be little reason to doubt its reappearance upon the Conemaugh in the great axis of Laurel Hill.

The long synclinal belt contained between the above axis (No. 1) on the N.W., and the Muncy Creek axis and escarpment of the Alleghany on the S.E., though geologically entitled to the name of a trough or basin, is, as we have seen when considering the topographical features of the region, rather a high strip of table-land, which the hard siliceous rocks below the coal have protected from denudation. The coal-rocks, the appropriate position of which is towards the middle of this table-land—that is, along the deepest or central line of the geological basin—by no means extend continuously along its summit, but are restricted to a few isolated localities by the converging dips of the lower strata, and occupy a medial line along the trough. An escarpment of the Seral conglomerate, upwards of 60 or 80 feet high, generally rises from the naked table-land of the Vespertine Sandstone, and marks approximately the margin or outcrop of the lowest coal-seam, which is here adjacent to the conglomerate. In these detached outliers we seldom find more than the three lowest coal-seams left, so great has been the destruction of the Coal-measures; and in the most Eastern or terminal patches we rarely encounter more than the first or second: therefore the total thickness of the coal-rocks above the conglomerate hardly exceeds in these cases 100 or 200 feet. Approaching the portion of the basin where they become continuous, their thickness of course augments.

The most Eastern tract of the Coal-measures in this basin is at the head of Mahoopeny Creek. The next patch W. of this is between the Big Loyalsock and its N. tributary, Birch Creek. In the latter locality there is one coal-seam over the conglomerate, about 2 or 3 feet thick, but it is more circumscribed than that rock in the area bounded by its outcrop: besides this one, there is a thinner seam imbedded in the conglomerate.

The high hills near the mouth of Plunket's Creek are capped by the Seral conglomerate; but no overlying coal-seam has been discovered on them.

The coal makes its appearance along the summit of the Alleghany Mountain at one or two points between this and the knobs W. of Pine Creek. On the W. side of Hogeland's Run there occurs coal 5½ feet thick, divided by 2 feet of fire-clay, and the outcrop probably of the same bed occurs on the summit, N. of Tombs' Run and overlooking Pine Creek.

Between Pine Creek and the Susquehanna West Branch, more especially around the tributaries of Queen's Run and Lick Run, there spreads a considerable patch of the formation. The maximum thickness of the Coal-measures in this neighbourhood is about 150 feet; the number of coal-seams is four: only three of these have such a thickness as to be valuable. In this tract are the mines from which it was intended to supply the Farrandsville Iron Works with fuel. Even here, a few hundred acres will most probably be found to embrace the whole of the productive Coal-measures, though the conglomerate, the usual external index to the coal, covers a considerably wider area. From the neighbourhood of the Queen's Run Mines, a long narrow ridge called Sandstone Hill marks the central line of the basin, extends E. to the turnpike, and protects the coal-bed, whose outcrop is there visible.

Passing now to the W. side of the Susquehanna, we come, after an interval of a few miles, to another isolated coal-tract between the forks of the Tangascootac Creek.

From this point to the Moshannon, the formation, although still extensively wasted and occurring only in a range of patches between the deeply denuded ravines of Beach Creek, begins to become continuous, and to present the outlines of a regular basin. In these tracts, where as yet no mining operations of any magnitude have been attempted, the ordinary number of coal-beds is two, or at the most three. One of the seams which is wrought to a small extent at Snow-shoe, probably the second or third in ascending order, is about 6 feet thick.

From the vicinity of Snow-shoe, which lies between the head-streams of Beach Creek, the Coal-measures may be regarded as extending S.W. in a narrow but continuous basin, confined principally to the N.W. side of the Big Moshannon, until within a short distance of Philipsburg, where the formation rapidly widens and increases somewhat in depth. Near this village the S.E. outcrop of the coal is within 1½ miles of the E. crest of the Alleghany Mountain.

From Philipsburg S.W., the centre of the basin coincides very nearly with the general course of the Moshannon Creek—the strata on each side dipping gently toward the stream. In Coal Hill there are four seams of considerable thickness.

The N.W. boundary of the trough lies from 2 to 3 miles N.W. of the Moshannon, in a high broad ridge, by which the first axis here begins to exhibit topographically its geological form.

A shallow depth of the coal-rocks, comprising probably only the lower seam, arches over this ridge, and thus connects the first with the second basin.

Whether the axis of this ridge, preserving its gentle sweep, and converging towards the N.W., becomes that of Laurel Hill, towards which it seems to point; or whether these two lie out of line like the sub-axes of Somerset County, hereafter to be described, has not been positively ascertained. S. of Mount Pleasant, the first basin loses its definiteness also, and, passing Ellensburg and the Pennsylvania Railroad, the widening space between the crest of the Alleghany and the Laurel Hill Axis, becomes separated into two, and finally into three basins, by the occurrence of anticlinal axes not developed further N.

CHAPTER II.

SECOND BASIN AND AXIS NORTH-WEST OF THE ALLEGHANY MOUNTAIN.

The next basin is that which contains the Towanda, Karthaus, and Clearfield coal-rocks. Like that of the first basin, its N.E. extremity in Bradford and Lycoming counties is a long narrow table-land, elevated nearly 1000 feet above the general water-level of the adjoining anticlinal valleys which bound it on the N. and S. The valley of the Towanda Creek is its immediate boundary upon the N. As in the case of all the N.E. terminations of this group of basins, the table-land which represents the more central parts of the trough, ranges as we trace it S.W. into a general high plain, where the anticlinal axes on the N. and S., instead of coinciding with valleys, are marked by broad swelling ridges, between which, as we proceed, the coal-formation assumes more and more the form of a basin, subsiding into a regular though gentle valley-like depression.

Second Coal-Basin, Towanda Mountain.—The anticlinal axis No. 2, which limits the basin on the N., exposes, from Towanda to the sources of the First Fork of Pine Creek, a narrow central tract of Vergent rocks, margined by the overlying Ponent strata, and forming a rough natural valley. From the First Fork to the Run called Chinchelamoose, in Clearfield County, it cleaves a long high belt of Umbral strata capped over large areas by the Seral conglomerate. The top of this anticlinal arch is traceable from the Northern waters of Wyalusing Creek across the North Branch of the Susquehanna at the Wysox bend, and thence up the centre of the denuded valley of Towanda Creek, below the second fork of Pine Creek, and crosses the Sinnemahoning a little E. of the junction of the Driftwood and Bennett's Branch, where, deflecting more S.W., it traverses a wilderness country to the Chinchelamoose Run, and there enters the Coal-measures. It is prolonged through the highland called Grampian Hills, and past the falls of the South Branch of the Susquehanna, beyond which it ceases in a few miles to be definitely marked; but probably, like the first axis in this same region, it sinks only to rise in bolder outline as the master axis of Chestnut Ridge.

From the Clearfield and Brookville Turnpike S.W. it is saddled by the lower coal-seams, and thus the second and third basins coalesce.

The long narrow trough in the strata, bounded on the N.W. by this second axis, does not embrace the coal-measures continuously, Eastward of the mouth of Kettle Creek, on the West Branch of the Susquehanna. Between this point and the North Branch it is a high table-land, contracting as we go eastward to a breadth of from five to seven miles, overlaid by the Vespertine sandstone, and capped in three or four localities by the coal-rocks. These latter strata consist of the Seral conglomerate, sometimes supporting the two or three lower coal-seams, sometimes entirely denuded of the proper coal-measures. Only two detached masses of the formation are here worthy of especial notice. The largest, and from its position the most important patch, is that which overspreads the highest summits between the Towanda Creek, and its middle and south branches. The other is on Lycoming Creek, north of Stony or Rocky Run, and around the sources of this stream and of Frozen Run.

Towanda Coal-field.—The Towanda coal-field has its Eastern termination on the brow of the mountain between the South Branch and the Carbon Creek, or the Middle Branch of Towanda Creek. Its Western limit is near the township line of Franklin. The Coal-measures, which occasionally embrace the two lower seams, occupy only the highest land, and form a rather narrow tract lying in an E. and W. direction. The whole of the coal lies within an area less than thirteen miles in length and four in breadth; but it is fair to infer from the gashed and denuded condition of this mountain summit, that the productive part of the formation does not constitute more than one-fourth of this surface.

The Lycoming or Ralston Coal-field.—The physical features of the Lycoming, or Second outlying Coal-field in the line of the present basin, are analogous to those of the Towanda tract. It caps a narrow part of the synclinal plateau in a series of detached flat knobs, and crosses Lycoming Creek as a narrow belt about seven miles long by less than two wide, the continuity of the coal-rocks being greatly broken by deep ravines and mountain valleys. Three coal-seams of useful dimensions occasionally occur, as at the mines near the head of Stony Run; while a fourth is at one place workable; and a fifth, low down near the conglomerate, also attains at one place a thickness of two and a half feet.

On both sides of Pine Creek, but especially on the Eastern, between the main stream and the First Fork, wherever the hills in the centre of the basin have a considerable elevation, the Seral conglomerate occurs in patches, and in one or other locality is accompanied by traces of the lowest coal-seam.

On the highlands between Drury's and Paddy's runs, and the Susquehanna and Kettle Creek, along Boon's Road, isolated patches of coal-rocks occur, and remarkably uniform traces are frequently visible, making the outcrop of the lowest coal-bed above the conglomerate.

But we may say that the regularly continuous Coal-measures of the Second Basin begin near the mouth of Kettle Creek, and follow thence the general course of the Susquehanna to its source, or at least as far as Canoe Place, at the S.W. corner of Clearfield County.

From near Clearfield to Kettle Creek the river flows nearly along the middle of the trough, supported by the Coal-measures as far as Moravian Run; but from this stream to the influx of Kettle Creek it cuts through into lower rocks, and cleaves the coal into two high narrow belts, one on each side of the deep trough in which the river winds. As the basin progressively deepens from the Sinnemahoning S.W., it embraces in that direction a very valuable thickness of useful mineral strata; and here, too, we first meet with those singularly persistent seams of limestone alternating with the coal, which prove such invaluable guides in identifying the series of coal-rocks over the whole region to the South and West.

At Karthaus the total depth of Coal-measures above the Conglomerate is at least 320 feet, in which are included nine beds of coal of various dimensions, besides beds of fire-clay and iron ore. (See Subdivision III., Chap. VIII.) It is probable that along Clearfield Creek, which for some miles seems to flow nearly centrally along the basin, the average thickness of the coal-formation is as great as at Karthaus.

The exact course of the basin S.W. from the head of the Little Clearfield Creek is not fully known; but little doubt can be entertained of the prolongation of the trough into that of the Ligonier Valley, between the axis of Laurel Hill and Chestnut Ridge. Should such be the case, we behold in the basin before us one of the most remarkable synclinal depressions anywhere discovered, whether we advert to its extraordinary length, to the regular sweep of the axes which bound it, or to their wonderful parallelism.

CHAPTER III.

THIRD BASIN AND ANTICLINAL AXIS.

Between the anticlinal valley of Towanda Creek, and the similarly-constructed broader valley-belt of Vergent and Cadent rocks of central Tioga County, on which are the sites of Covington and Wellsborough, we encounter a third synclinal table-land, ending abruptly N. of the village of Canton Corners, and marking the termination of the Third Basin.

Originating, as mentioned, between the Forks of Sugar Creek, E. of the Tioga County line, it extends as a narrow irregular detached plateau, nearly to Pine Creek, where it joins the general table-land of the country. From its Eastern termination at Canton Corners to Bennett's Branch of the Sinnemahoning, the whole belt included in the Basin is generally overspread by the Umbral shales and Vespertine sandstone, supporting near its central line a few isolated tracts of the Coal-measures, and a rather larger number of the patches of the Seral conglomerate, from which the superincumbent coal-rocks have been entirely swept off. Immediately S.W. of Bennett's Branch, we enter upon the continuous Coal-measures of this Basin, which extend thence in a regularly thickening mass to the Conemaugh.

The anticlinal axis which confines this long and narrow trough on the N.W. axis No. 3, approaching from the N.W. corner of Susquehanna County, crosses the North Branch a little below Tioga Point, the Tioga River about two miles North of Covington, and Pine Creek near the Round Islands. Thus far it elevates a wide belt of the Vergent and Cadent strata, margined by the Ponent red sandstone, here much attenuated in thickness.

From Pine Creek its range is S.W. to Trout Run of Bennett's Branch, which it crosses about three miles N.W. of Winslow. Beyond this point, it sweeps steadily to the southward, through the high range of the Elk Mountain, crosses the East Branch of Sandy Lick Creek, near the Western line of Clearfield County, and passes about two miles West of Punxutawney. Its course thence to the Kiskiminetas, or Conemaugh, is slightly irregular, intersecting Little Mahoning Creek, East of Smicksburg, passing close to Middletown, and crossing the Kiskiminetas about three miles E. of Warren, or a little E. of Roaring Run (Routing Run on the Map).

From the Round Islands on Pine Creek to the East Branch of the Sinnemahoning, the third axis exposes, for the greater portion of the distance, a belt of the Vespertine sandstone, although in crossing the eastern streams of Kettle Creek it exhibits upon the sides of their deep valleys the Upper Vergent rocks and the thin Ponent series; for it must be held in mind that the general water-level of the streams which reticulate the whole of this vast region is always many hundred feet below its plateau surface. Beyond the Sinnemahoning, as far as the S.W. termination of the Elk Mountain, the coarse rocks of the Seral conglomerate rise high upon its sides, while the Umbral Red Shale arches over it at its surface stratum. But at the Southern end of Elk Mountain the Coal-measures, encroaching from both sides upon the stratum of Seral conglomerate, unite or close over the axis before it reaches the East Branch of Sandy Lick, and from this point of junction, to the termination of the axis S. of Kiskiminetas, it is arched by a thicker and thicker body of coal-rocks.

The Blossburg Coal-field.—The only one of the detached coal-fields appertaining to the Third Basin which merits a place in this general description—indeed, the only one of any magnitude—is that of Blossburg on the head-waters of the Tioga River. It lies N. of the upper part of the river, the part that flows from E. to W. along the middle of the trough, partly in Bloss and partly in Ward townships, and extends about eight miles Eastward from Blossburg in a narrow elliptical form. The total thickness of the Coal-measures is about 200 feet, the hills containing the formation having an elevation of about 400 feet above the bed of the river. The coal-seams near Blossburg, counting great and small, are about nine in number; five of these being small non-persistent beds, and the others not averaging more than 3½ feet in thickness, excepting at one locality on Morris Run, where the main bed exceeds 5 feet in thickness. They are accompanied by beds of fire-clay, and some iron ore; but, as in all these extreme N.E. prolongations of the several basins, limestone seems wholly wanting. (See sections at Morris Run and Blossburg.)

Between Boon's and Johnson's Creeks, about three miles Westward of the Tioga River, and in geological line with this main field, there is a much smaller and thinner patch of the coal-rocks, including probably a few of the lowest seams.

In the same line, still further to the S.W., is another still more shallow portion of coal-rocks. This ranges across Wilson's Creek to Stony Fork, and lies between 8 and 9 miles S. of Wellsborough. Here are two beds, both of moderate size.

Though many outlying patches of the Seral conglomerates occur along the middle of the trough, from Pine Creek to Driftwood Branch, that rock in all this distance nowhere supports any tracts of the Coal-measures, or none deserving consideration here. On the W. side of the Driftwood a single seam has been discovered, near the level of the highest land, but occupying a very circumscribed area. The cause of this is to be found in the unusual narrowness of the Basin here, with no increase of steepness in its synclinal dips.

The Coal-measures begin to occupy continuously the third basin at Bennett's Branch of the Sinnemahoning, S.W. of Trout Run; the former stream, from its source to within 2 miles of the latter, flowing nearly in the centre of the trough. From Sandy Lick Creek and Anderson's Creek S.W., the Coal-measures of this basin are united with those of the adjoining second and third basins across the intervening axes; but from these streams N.E. the belt regularly tapers and grows shallower to its termination at Trout Run.

At Caledonia, on Bennett's Branch, about 5 miles above the mouth of Trout Run, the coal-rocks, including the conglomerate, which is about 100 feet thick, compose nearly the entire series of strata from the flats of the stream to the hill-tops, making in all a thickness of about 500 feet. In the 400 feet of Coal-measures occur

6 distinct seams of coal, 3 of these possessing sufficient thickness to be valuable. There are likewise 3 or 4 beds of limestone, and some layers of shale rich in iron ore.

Where the Brookville and Clearfield Turnpike crosses this basin, the lower beds of coal arch over the third axis on the W. into the fourth basin, while in the centre of this third basin 3 seams of coal have been proved, while two others may possibly exist: near the hill-tops a bed of limestone is also found.

At Punxutawney the W. or third axis has so subsided that the limestone (known by us as the Freeport Limestone) and underlying coal-bed (here the only valuable one, and 8 feet thick) outcrop upon it, while a very great depth of the still higher unproductive measures cover the surface, or fill the bed of the basin itself. These, as we pass on S., still increase in thickness, until, to the S.W. of the town of Indiana, and along the centre line of the basin, we find the great Pittsburg coal-seam, capping the highest knolls between the streams, itself sinking deeper and deeper very gradually under overlying rocks, until, at the Kiskiminetas, 3½ miles W. of Saltzburg, not less than 175 feet of upper measures, containing two unimportant coal-seams, overlie it.

As a consequence of the great thickness of the Barren-measures—about 500 feet—and the absence of the coal which overlies the Pittsburg Coal, possibly that which attains such important thickness at Karthaus and other places to the N.E., the Freeport Limestone and Coal are the only beds of value found along the edges of this part of the basin we are describing. But as a heavy limestone mass has preserved the surface-land from excessive denudation, and left it comparatively level, we find that these beds are widely spread over the face of the country to the W. of the town of Indiana, being brought up by the third axis in all the creeks, where they afford the people an abundance both of fuel and lime.

Considering the axis of Chestnut Ridge as the most probable E. boundary of this basin, we may add that all along its line the lower coal-seams crop out. At Blairsville there are 2 seams of considerable size, each underlaid by a bed of limestone; and E. of that town the conglomerate begins to saddle the axis.

CHAPTER IV.

THE FOURTH BASIN AND ANTICLINAL AXIS.

A HIGH narrow range of mountains, deeply and frequently gashed, and similar in all respects to the two first described, stretches from the Tioga River W., between the anticlinal valleys of Wellsborough on the S. and the Cowanesque Creek upon the N. Composed at its base of the upper part of the Vergent rocks of the valleys—embracing higher on its sides the grey Vespertine sandstone and Umbral shales, the Ponent red rocks having nearly thinned out, and its summit capped here and there with larger or smaller patches of the Seral conglomerate—it rises from the rolling land of Bradford County, which it overlooks, 5 or 6 miles E. of the Tioga River. This stream flows transversely across it, and ranging away W. by S. along the N. side of Pine Creek, is finally lost in the general upland of S. Potter and McKean counties. There the coal-rocks, which to the E. are found in exceedingly small patches at the summits, occur more frequently, and after passing the Driftwood Branch of Sinnemahoning, become a continuous basin, growing regularly deeper towards the S.

It may be well to speak here of a topographical peculiarity of these projecting mountain terminations of the several basins towards the E., because the opportunity presents itself in the basin under consideration for, perhaps, its happiest illustration. Recognising the general law of water-courses, as descending from the centre lines and summits of mountain-ranges to the plain, the spectator is here surprised to see the various streamlets take their rise along the centres of the intervening valleys, and, flowing towards and into the mountain, there unite and divide it lengthwise; and when they finally flow away to the nearest river N. or S., seeking an exit by a separate gap. A glance at the map will exhibit this remarkable phenomenon, while its explanation will be afforded by reference to General Sections, Nos. IV. and VI., in which it may be seen that the waters take their rise along the line of axis in the valley, flow down the dip of the rocks toward the mountain, and collect in streams where the synclinal trough is deepest.

Thus is the mountain-range of the first basin furrowed lengthwise by the Mahoopeny and Loyalsock; that of the second, by the Middle Branch of Towanda Creek; the third, by the head-water of Tioga River; and more remarkably, the fourth and fifth by the branches of the Crooked Creek and Cowanesque. So with the first and second forks of Pine Creek, and waters further W. All these streams have the tendency to seek and flow along the middle of each basin, and leave it only when they seek their final exit into the lower country N. or S.

The course of the fourth axis, which crosses the Tioga River 2 or 3 miles N. of the State line, is easily traceable along the valley in which flow the tributaries of the Cowanesque; but after entering the wild upland at the heads of Pine Creek and the Alleghany, it becomes difficult to tell its exact position. An almost unbroken forest covers the greater part of Potter County, in which the indistinct indications of the very gentle dips that distinguish the last 3 basins universally conceal themselves. Crossing the Driftwood, 3 miles above Portage or Emporium, and perhaps 10 miles above Axis No. 3, the fourth axis ranges up the bed of West Creek, and brings to view, in the creek, the upper edge of the Vergent rocks and the Ponent red sandstone; while the Vespertine and Umbral series appear in the hill-sides, and to some extent overspread the face of the country above. Thence curving regularly to the S.W., between the Clarion River and the Little Toby, and ranging through the central parts of Elk County, it crosses the S. Branch of Sandy Lick Creek, 2½ miles E. of Port Barnett, Little Sandy Lick Creek, 3 miles from its junction with the Red Bank Creek, and the Mahoning, near the mouth of Glade Run. After passing the Cowanshannock, 7 miles E. of Kittanning, it crosses Crooked Creek, 3½ or 4 miles from the Alleghany River, and dies away upon the Kiskiminetas, 2½ miles from its mouth.

Along its whole course from Tioga River to the head-waters of Trout Run, with the exception of patches of Seral conglomerate, it is covered by the Umbral shales and sandstone rocks of the Vespertine series; but from the Little Toby Creek, towards the S., by an increasing thickness of Coal-measures.

The Coal-Measures.—But one bed of coal above the Seral conglomerate is found in this basin, E. of the Driftwood Branch, and that one only in small isolated patches along the central line, and at the tops of the highest hills. It is seen at one or two points on the Pine Creek waters in Tioga County, and on the Driftwood. At the former localities it is very thin, but increases in importance as we go W. On the Driftwood it measures 4½ feet in thickness, and is found 50 feet above the conglomerate.

After passing the Ridgway Turnpike the basin rapidly deepens, and contains, on the Little Toby and Brandy Camp creeks, six beds of coal, 3 of which display a thickness of 3 feet. Three beds of limestone accompany them in various localities.

At the Brookville Turnpike the lower beds arch over into the third basin last described, but continue to crop out towards the W. upon the flanks of the fourth axis. This is due to the shallowness of the basin, and its very gentle subsidence towards the S.W. The higher beds, those of the Freeport series, are not therefore found in it, until we pass S. of the Turnpike, when they assume their places in the centre of the trough; and as we continue to go S., they spread gradually over it, and at length arch over either axis into the basins to the E. and W. At this point the central line of the basin is occupied in turn by the higher unproductive measures.

At the crossing of the Turnpike on the E. Branch of Sandy Lick Creek, are 3 beds of coal and 2 beds of limestone. The uppermost bed here is a noble coal-seam 8 or 9 feet thick.

At Smicksburg, on the Mahoning, are found the Freeport upper and lower coal-seams, with their included limestone stratum, the upper coal-bed measuring 4½ feet in thickness. From the Mahoning S. to the Kiskiminetas these beds are the common ones of the basin, occurring at the level of most of the small streams, while the hills above are composed of unproductive higher measures.

CHAPTER V.

FIFTH BASIN AND ANTICLINAL AXIS.

A FIFTH synclinal range of mountain-land, similar in all respects to the preceding one, enters the State along the Northern line of Tioga County, bounded on the S. by the straight valley of the Fourth or Cowanesque Creek axis. Its Northern limit, which enters the State at the extreme N.W. corner of Tioga County, is irregular, and is not traceable by a mountain escarpment. In New York State this range of Carboniferous strata terminates in the neighbourhood of the Tioga or Chemung River.—(See the New York Geological Map.) No Coal-measures have been discovered capping its conglomerate covering, until we approach Coudersport. The upper of the Vergent series sweeps from the valley of the Cowanesque Creek, around its termination in New York, and ranges along its Northern margin.

Its connection with the general table-land of Potter, M^cKean, Elk, and Forest counties, is accomplished without any abrupt change of topographical character; first, because of the increasing gentleness of the dip which marks the successive basins as we proceed N.; and next, by reason of the increasing agreement in structure between the rocks of the Vergent, and Vespertine and Umbral series, in the same direction. By the former the results effected by general denudation become less definite along the lines of the trough and anticlinal axis, the flexures disappearing in an almost universal horizontality. By the latter, the difference in amount of denudation upon the rocks of the valley and the rocks of the mountain grows smaller Northward, and forbids that boldness in the synclinal mountain escarpments here, which gives its clearest feature to the region of the basins further S.—(See General Section VI.) Thus the whole country is much elevated, and at the same time deeply and irregularly grooved by all the water-courses. In these, especially along the line of the fifth axis, the Vergent rocks are discovered; their upper edge being at a less or greater height above the water-level, while the chief portion of the country above is composed of the Vespertine sandstone and the Umbral formation, on which, between the streams, and generally along the middle of the basin, lies the massive stratum of the Seral conglomerate. This will better be described in connection with the coal.

The curve of the Fifth and last axis conforms, as far as it is known, with that of the axes to the S.E. of it, being difficult to trace with accuracy as to its summit-line, because of the extreme slightness of its dips both Northward and Southward. It enters Pennsylvania near the Genesee River, crosses Potato Creek near Smethport, bends Southwardly through the wilderness of M^cKean and Elk counties, crosses the Clarion River 5 miles below the mouth of Millstone Creek, and the Brookville Turnpike W. of the Old State Road between Kittanning and Olean, and entering the country W. of the Alleghany River, between the mouth of the Mahoning and that of Red Bank Creek, passes on between the heads of Deniston's and Limestone Runs, crosses Buffalo Creek 3 miles above Worthington, and dies out in a line 3 miles W. of that village.

From the entrance of this axis into the State, as far as to the Alleghany River near Smethport in M^cKean County, it is everywhere covered by the Vergent and Vespertine series, the limits of which, as distinct formations, have not yet been clearly defined. Thence Southward beyond the Clarion it supports the Seral conglomerate strata, arched in one or two places by the lowest coal. Where the deep and narrow valleys of the streams—and these are very numerous—have cut through the conglomerate, the rocks below it are exposed. At the Brookville Turnpike, the first great Seral sandstone above the conglomerate is for the first time clearly recognised arching the axis; and then successively follow, from this point Southward, the beds of the Clarion and the Freeport groups. The former throw their outcrops, one after the other, across the axis, between the Turnpike and the Alleghany River; the latter do the same beyond the river.

Coal Beds of the Fifth Basin.—The central line of the Fifth Basin passing about 5 miles to the N. of Coudersport, a single coal-bed is found in many localities above the Conglomerate, but it is of no great value. As we proceed Westward the measures are increased by the addition of the Tionesta sandstone, with several beds beneath it, and one or two of the coal-beds over it. This is the case on the highland on each side of Potato Creek, to the S. of Smethport, and a few miles still further W., where we have a number of coal-beds several feet thick, and a limestone stratum 15 feet thick.

The N.W. outcrop of the Coal-measures here coincides very nearly with the course of the Turnpike Road from Smethport to Ridgway, the Fifth axis bringing up the rocks of the Seral conglomerate N. of the Turnpike.

The Basin, as we follow it towards the S., deepens very little, if at all, and we have at Brookville the same beds as in its more Northern portion. At the tops of the highest hills, here and there, along the centre of the basin, even as far to the N.E. as Instantur, limestone is sometimes found, but nowhere as a valuable continuous bed, until we descend the Red Bank Creek, where the basin rapidly deepens, and the whole of the Clarion group, with its top sandstone, the Freeport sandstone, becomes well developed. At Kittanning, the Tionesta sandstone has sunk below water-level, and at Freeport the whole Clarion group, its place being occupied by the group next above, or the Freeport group; while the bottom rocks of the still higher Barren group cap the hills.

In this more Southern part, the Fifth Basin is fruitful of coal and limestone. Along the Red Bank Creek and its tributaries, we everywhere meet with the Brookville, Clarion, and Kittanning coals, and the limestone of their series, the Ferriferous. The three coal-seams mentioned average 3 feet in thickness, and the limestone is always a useful bed, from 4 to 6 feet thick, frequently supporting a stratum of iron ore, much sought for, and often very valuable. These beds, as has been said above, arch over either axis into the Fourth and Sixth Basins, and therefore to the S. must be conceived of as spreading through the whole country, until they gradually sink below water-level. Upon the Alleghany River, below the mouth of the Mahoning Creek, the ferriferous limestone becomes a most important stratum, averaging for many miles full 15 feet in thickness, and sustaining generally a peculiar buhrstone ore upon its upper surface. The latter is often 1, 2, and even 5 feet thick, as at Alleghany Furnace. Between Freeport and Kittanning, however, these valuable rocks sink together gradually below the bed of the river and the general water-level of the middle of the basin, and the thinner limestone of the Freeport group next above descends with equal gradations from the highland, and takes its place, accompanied by the upper and lower Freeport coal-beds, each averaging in thickness about 3 feet. These are the common beds of the country to the E. and W. of Freeport, and their outcrops in the Sixth Basin will be traced as they stretch through it into the State of Ohio. The Elk Lick bed of coal, which we have reason to believe much more irregular than any of the rest, is poorly represented in this basin, and is only once found to be workable. This locality is upon Crooked Creek.

The lowest or Tionesta group is also poorly developed in the S.W. part of the Fifth basin, being destitute of limestone, and generally with but one coal-bed, and that of very moderate size.

CHAPTER VI.

THE SIXTH COAL-BASIN AND FINAL OUTCROP OF THE NORTH-WEST.

A LINE drawn in a W.S.W. direction from Kenzua on the Alleghany River, near the Western county-line of McKean, through Sandy Lake, Mercer County, to Youngstown, on the Mahoning River, in the State of Ohio, will define with tolerable accuracy the North-western limit or outcrop of the lowest coal in this Sixth and last basin of the great Bituminous Coal region. This outcrop is, however, by no means a straight line; for every valley along this boundary-line, and for many miles inward to the S.S.E., cuts necessarily down through the coal, and develops the lower rocks, even far down into the Vergent series. Thus every intermediate high hill or patch of table-land becomes an isolated coal-field, less or greater in area, according to circumstances, dependent upon the amount of local denudation.

Beyond this line, North-westwardly, none of the Coal-measures above the Seral conglomerate extend; but the conglomerate itself, in an irregular band, ranging parallel to the line, caps all the land between the valleys, and presents in its turn an escarpment towards Lake Erie, along a line drawn parallel to, and at an average distance of 10 miles from that above given. The Vergent strata issue from beneath the conglomerate, and occupy in a succession of terraces the rest of the distance to the shore of the Lake; while the absence of the Vespertine and Umbral series is accounted for by the complete thinning-away of those strata or by their coalition with the upper Vergent rocks, so as to be quite indistinguishable lithologically from them.

Beneath the Conglomerate we find, in place of a well-defined Vespertine stratum, a small group of Coal-measures, which will be presently described, and an analogy drawn between them and a series holding a similar position in the extreme Southern part of the State.

It only remains to add, that outside of the band of conglomerate mentioned above, there occur here and there, upon the very highest grounds, several small outlying patches of that rock which have resisted the general denuding force which has elsewhere laid bare the upper surface of the lower rocks. One such, for instance, may be found upon the State line of New York, in the N.W. corner of Warren County, and several others around Meadville. The shape and size of these in their superficial area can only be usefully known by a reference to the Map.

Coal-Measures of the Sixth Basin, Tionesta Group.—Commencing our description of the Coal-measures of the Sixth Basin at the N.E. end, as usual, it may be remarked, that from the Genesee River to the Tunamaguont * Creek the country between the water-courses is everywhere overspread by the Seral conglomerate, no coal being seen, with the exception of one small seam below the conglomerate, until we reach the head-waters of the latter stream. Most of the valleys expose the conglomerate; the underlying sandstones and shales, with their included limestone beds, are all of carboniferous age, and the deep red slates probably of the Ponent and Vergent sandstones, here perhaps 100 feet in thickness, often occur at the water-level.

The first coal-beds above the conglomerate make their appearance on the head-waters of the Tunamaguont, and at the nearest point about 5 miles to the W. of Smethport. An outlying patch about 4 miles long, and 1½ miles wide, is seen between the branches of Sugar Creek to the E. of Kenzua village, and several smaller areas occur still further E. towards Tunamaguont. About 4 miles W. of Kenzua, on the opposite side of the Alleghany River, occurs a very small patch of the same; and there is an extensive area of it along the N.E. side, and between the main forks of Kenzua Creek and the head-waters of the Clarion River.

From the line of Kenzua Creek S.W., the area of the coal becomes, so to speak, continuous, because only intersected by the very numerous ravines of denudation. A little S. of the mouth of Tidioute Creek its N. edge crosses the Alleghany River, and thence to Oil and French creeks, it occupies seven larger patches of table-land between the larger creeks. Its limit to the S.E. is parallel to, and 2 or 3 miles distant from, the crest of the fifth anticlinal axis, until that axis strikes the Clarion, where this group of strata arches over it, and runs back in the basin last described towards the N.E.

Over all this country, to the E. of the Alleghany River, and as far down towards Kittanning as they have been found, being occasionally brought to view by the axes, the two or three coal-beds of this group are unimportant seams, seldom exceeding 1½ or 2 feet in thickness, and being generally poor in quality. They occur to the N.E., within a mass of shales, from 40 to 60 feet in thickness, over which is spread the great Tionesta sandstone of nearly equal bulk. This sandstone stratum forms the surface of every plateau between two streams, as far as the Clarion River. There it begins itself to be covered in turn by the rocks of the Clarion series.

West of the Alleghany River and French Creek, a great change is observable in the rocks between the conglomerate and the Tionesta sandstone. This change attains its maximum in the neighbourhood of Mercer, where we find the interval to reach 100 feet, and to contain four coal-beds, the upper one, the Tionesta Coal, being 6 feet thick, and the other three averaging 1½ feet in thickness, with a limestone bed (the Mercer Limestone) sometimes 4 feet thick. Still further to the S.W., and in the neighbourhood of Newcastle, on Beaver River, another limestone bed (the Mahoning Limestone), 2 feet thick, is interposed immediately under the Tionesta sandstone; while the Tionesta Coal-measures have there resumed their former insignificance as productive strata.

Sharon Group.—In the neighbourhood of Sugar Lake, 10 or 12 miles N.W. of the town of Franklin, a series of rocks, resembling the Coal-measures, makes its appearance beneath the main body of the Seral conglomerate. This group of coal-strata is not to be considered as a lower coal-formation, but as merely a part of the lower group of the Coal-measures, locally developed by increase of the coal-beds, and a proportionate reduction of the pebbly matter of the sandstones. Becoming better developed as we trace it N., it is found to consist usually of a single coal-bed from 12 to 20 feet below the base of the conglomerate, generally quite thin and poor, but attaining, in the neighbourhoods of Georgetown and Sharon, the thickness of 5 feet.

At intervals of 15 and 20 feet below this bed, are found in one locality, 6 miles N.W. of Mercer, two other coal-beds, 1¼ and 2½ feet thick respectively. At Georgetown, valuable iron-ore overlies the bed first described.

---

* Sometimes Tunuangwant; but we spell here as in the "Gazetteer of the United States."

Small as this coal-seam generally is, it is known to extend to a great distance, as it has not only been found to the N., at Meadville, and to the S. at Lawrenceburg, but as far down the Alleghany River as the mouth of the Mahoning Creek, where it is represented by three very small seams, each only a few inches thick.

Clarion Group.—The base of this group of coal-bearing strata, which measures in many places 175 feet, though in one district it is said to be 98 feet, is the Tionesta sandstone, a coarse grey or yellowish rock, sometimes much blotched, and streaked with peroxide of iron, and overspreading, as mentioned above, all the N.E. part of the Sixth Basin. In the higher hills about Lafayette, and at the head-waters of the Kenzua, it is capped by a body of coal-bearing strata, including, in some places, five or six distinct seams of coal. We have not followed the basin critically through the wilderness of Forest County ; but the rolling character of the trough itself, when so immensely expanded, does not favour increased thickness of coal-strata within it going S.W. Thus, as far S.W. as Racoon Creek, in Venango County, we find knolls and small ridges, containing only one or two beds of coal, above the Tionesta sandstone (the Brookville and Clarion coals), which sometimes have their summits covered with fragments of the next superior bed of limestone, the Ferriferous limestone. These, however, soon become continuous beds, and are overlaid by the Kittanning Coal-bed in Richland and Beaver Creek townships. The outcrop of this latter bed is far more irregular than usual, and more difficult to trace, because, instead of being protected by a hard stratum of sandstone, it supports, and is supported by, many feet of soft argillaceous shales, affording little or no resistance to the denudation, which, in acting readily upon the shales, has also swept away the included coal. This is the case along its N. and N.W. outcrop, where the Freeport sandstone, which is the upper limit of this group, is separated from the coal by many feet of such shales.

Outcrops.—In tracing the outcrops of the coal-beds in the Sixth Basin, it should be noticed as preliminary, that the two counter-dips of the basin are very unequal in length. The dip from the N.W. is not more than one-seventh of a degree ; while that from the axis towards the N.W. diverges 2°. Hence the geological centre-line of the basin or synclinal axis ranges parallel with the fifth axis not more than 5 miles distant. It is in this line, of course, that the beds have their greatest N.E. prolongation.

The Brookville Coal.—This bed, lying immediately upon, or a few feet above, the Tionesta sandstone, has an irregular outcrop, coinciding in the main with that of the Clarion coal and Ferriferous limestone above it, and it will be best described with theirs. To the N.E. and E. this coal is a large and useful bed ; but it dwindles away, and almost disappears when traced W. towards the Ohio River. In Rockland township, S.E. of the town of Franklin, it is divided into four beds about 2 feet apart, the lowest measuring 5 feet, and the whole containing 7½ feet of coal. This is indeed an unusual thickness for this coal-seam, and only a few miles off it consists of three seams, which are in all but 2 feet thick. Its average thickness along the fifth axis and the Clarion River may be considered to be 4 feet. Further down the Alleghany River, and on the Kiskiminetas it seldom exceeds 1 foot, and upon the Ohio River, and in the neighbourhood of Beaver, it is found varying from 2 to 6 inches in thickness ; while higher up the Beaver, as at Newcastle, it again assumes a thickness of 3 and 4 feet.

Clarion Coal and Ferriferous Limestone.—The extreme N.E. limit of the uppermost of these beds, the limestone, is, as far as known, just within the line of Forest County north of the Clarion River. Although a section of the strata in M'Kean County represents coal-beds certainly higher in the series than this limestone, no trace of it is yet discovered.

The Clarion Coal-bed, which is about 15 feet under it, occurs in patches somewhat beyond the limit of limestone above indicated. But by drawing a line through the outermost patches of the limestone, the outcrop of the Clarion Coal-bed will also be determined. Such a line will cross the fifth axis, near the Brookville and Franklin turnpike ; thence curving, to range nearly parallel with and about 2½ miles from the axis, it will cross the Clarion, and sweep round close by the S. head-waters of Racoon Creek towards Franklin, until it reaches Pine Creek, a branch of Six-mile Run. Here it will bend to the S.W., cross the Alleghany a mile below the bend at Scrubgrass Creek, and thence pass due W. to within 5 miles of Mercer. There it turns to the S., crosses Hart's Run 3 miles from its mouth, and ranges down to the mouth of the Little Neshannock, and so down the W. side of the Neshannock Creek to Newcastle. As it merely touches on the high ridge S. of New Bedford, its outcrop may be said to enter the State of Ohio south of the Mahoning.

In thus tracing the outcrop of the Clarion group of coal-beds, we have left out of consideration the Coal-measures based upon the Tionesta Sandstone, in M^cKean County, because the limit of those seams is very imperfectly known, and there is difficulty in a satisfactory correlation of the strata.

The Clarion Coal-bed exhibits a variation in thickness similar to that of the Brookville Coal, but the direction in which this difference increases is nearly opposite. This bed thickens to the S.W. as that one does to the E.; but in neither case is much regularity in increase or decrease to be reckoned upon. It is scarcely 1 foot thick anywhere along the Clarion and Red-Bank, in the neighbourhood of the fifth axis; but as we go W., it increases in thickness. At Shippenville it is 2½ feet; on Rocklar Creek, 3½ feet; and in the N.W. corner of Butler County, in one locality, it is 6 feet thick. On the Beaver River its average thickness is about 2½ feet.—(See the Sections).

In the N. townships of Butler County, and in Scrubgrass and Irwin townships of Venango County, the 30 or 40 feet of brown shale which separate this coal-bed from the Brookville coal below it are the chief repository of the nodular iron-ore made use of in that part of the country.

The Ferriferous limestone is so called because, in many localities, such as the Deal Bank, near Shippenville, on Point Creek, and at the furnaces W. and S. of Kittanning, a very valuable deposit of iron ore rests directly upon it, while in other localities the bed of limestone itself seems to be divided between carbonate of lime and carbonate of iron. This ore is accompanied by a species of chert called "The Buhr-stone," which, as seen on Point Creek, is compact in its texture, externally grey, but light blue where newly fractured, and usually interposed between the limestone and the ore. The latter is variable in its character, sometimes a solid hard blue fossiliferous stratum like limestone, again consisting of crusts or shells, which contain cavities and perfectly-formed nuclei. It varies in thickness from 6 inches to as many feet.

This limestone band, which apparently has its N.E. limit along the Susquehanna and Sinnemahoning waters, although its Eastern point has not with certainty been fixed, retains, nearly to the Alleghany River, a very uniform character, and a thickness seldom exceeding 4 feet. As it approaches this stream it increases in size, being 10 feet in thickness at Franklin, and 15 feet at Kittanning. On the Beaver River, still further to the W., it is 12 feet thick, and 20 feet at its point of subsidence, beneath the water-level of the Ohio River. It is usually a blue carbonate of lime of compact structure; but it is often of a grey-blue colour, hard and solid, with a few fossils, Atrypa, Encrini, and Terebratulæ. Sometimes, as in the Sandy Lake township, S.W. of Franklin, it is even divided into two beds by more than 12 inches of clay, and a few inches of coal.

The Scrubgrass Coal-bed.—Underneath this limestone bed, at several localities, in the country lying between Newcastle and Franklin, a small coal-bed makes its appearance, worthy perhaps of notice in this summary, although its maximum thickness is but 20 inches. At Newcastle the limestone lies immediately upon it; elsewhere, a few feet of other strata intervene.

In the basins to the S.E., the first coal-bed over the ferriferous limestone is the ferriferous coal; but in the country we are now describing, that bed is never found. The next in order, therefore, is the

Kittanning Coal-bed.—This coal-seam lies generally about 30 feet above the ferriferous limestone; but sometimes the interval amounts to 67 feet, as on Beaver River, and even to 80 feet, as on the Clarion. Throughout this basin it is everywhere very uniform, averaging 3 feet in thickness, seldom becoming less than 2 feet, and never more than 4 feet thick. Upon the Clarion, W. of Brookville, however, it suffers a local diminution, which reduces it to a thickness of a few inches.

Its outcrop crosses the Fifth Axis, between the head-waters of Leatherwood Creek and Licking Creek, passes on N. and N.E., parallel to and close by the axis, bends round sharply near Roseburg, skirts the Clarion Valley, which it crosses at the mouth of Deer Point Creek, proceeds thence N. to Shippenville, and then turns and crosses the Alleghany 3 or 4 miles above the mouth of the Clarion. It then ascends the W. side of the Alleghany River for a short distance, takes a Westerly course, parallel to, and about 7½ miles N. of the Butler and Venango County line, and closely approximates the outcrop of the ferriferous limestone-band, before described, upon the Neshannock Creek. The outcrop of the coal-bed, however, keeps off again, down the S.E. side of the Neshannock Valley, and crossing the Beaver River at the mouth of the Mahoning, strikes off due W. into the State of Ohio.

The Freeport Sandstone.—This second great Coal-measure sandstone—the base of which on Red Bank Creek, is 75 feet above the Kittanning Coal last described, and the top of which, opposite the mouth of Red Bank Creek, immediately underlies the Freeport Coal, next to be described—is by no means an invariable component of the Coal-measures. Although spread out as a persistent member of the great series over a vast extent of country, from Somerset County to the S.,* and beyond the Alleghany River to the W., to the extreme N.E. limits of the Third Basin, where it seems to have had an agency in preserving from more extensive denudation the coal of the Blossburg field, we find it frequently degenerating locally into shaly sandstone, more or less coarse, or even into shale of only a few feet thickness. This is especially the case toward the N.W. limit of this sixth basin.

The Freeport Group.—The outcrop of the lower Freeport Coal-bed enters the sixth basin over the fifth axis, at a point a mile or two W. of Worthington, 7 miles from Kittanning, and ranges along the W. side of the axis to the mouth of Red Bank Creek. Reaching Licking Creek, it recurves, and again crosses the Alleghany River 3 miles below Lawrenceburg. Thus a portion of the area covered by this coal-bed is prolonged across the Alleghany River, but it is of trivial dimensions, not exceeding in its widest part 7 miles in breadth, nor nine miles in its entire length, and holding also within these narrow limits the still smaller concentric areas of the two superior beds of limestone and of coal that will next come in order for description. From the W. side of the Alleghany River, the outcrop of the lower Freeport Coal-bed takes a W. by N. course to the Butler and Scrubgrass Road. Here it turns slightly more N.W., and trends in a very straight line to a point upon the Beaver River, 2½ miles N. of the mouth of the Conequenessing Creek, and thence to Fairfield in Ohio.

The outcrops of the Freeport limestone and upper Freeport coal, nearly coincident, cross the fifth axis at a point 7 or 8 miles to the S.W. of that at which the outcrop of the coal-bed last described crosses it—a parallelism which they generally maintain. Stretching first N.E., they cross the Alleghany close above the influx of the Red Bank Creek; they enclose, as has been said, a small area on the E. side of that river, and recross it at the bend, 2½ miles above Catfish Creek. Still keeping a direction parallel with that observed by the outcrop of the coal below, and projected somewhat N. near the Butler and Scrubgrass Creek Road, they cross the Beaver River four miles below the mouth of Conequenessing Creek, bend N. up to Greensburg, and then make their escape W. into Ohio.

While the interval between the upper and lower Freeport Coal-beds varies incessantly, that between the Limestone Band and the Upper Coal preserves great uniformity. In the region under notice, the limestone is everywhere found within 10 feet of the bottom of the coal. Often, as at Old Brighton, and below it on the Beaver River, 2 or 3 feet of fire-clay is all that intervenes. The thickness of interposed rocks between the limestone and the lower coal at the extreme N.E. end of the area—that is, on the Alleghany River—occupied by these beds, is about 40 feet, but it increases as we follow them towards the Ohio. On the Beaver River, 70 feet of brown shales occur between them; below Kittanning the interval is equally great. At Butler, and towards the State of Ohio, upon the Ohio River, there is an interval of 75 feet.

The Lower Freeport Coal.—This bed is generally small. If its average thickness over the whole region were estimated, it would scarcely exceed 1½ feet. Occasionally, however, it assumes an importance which elsewhere does not belong to it. At Beaver River, on a fork of Trough Run, it measures 4 feet 3 inches of semi-cannel coal; and three miles above the mouth of the Connequenessing, its thickness is fully 6 feet. In the neighbourhood of Worthington it lies immediately upon the Freeport sandstone, the basis of the series, and is separated from the Kittanning coal below by about 50 feet of strata. Upon the Alleghany River the same interval is increased to 135 feet; while on Tomlinson's Run, in Ohio, it is only 23 feet—the coal itself measuring from 4 to 6 inches.

The Freeport Limestone.—This widely-extended bed averages a little more than 3 feet in thickness, though from Kittanning downwards along the river it increases from 5 and 6 to even 10 feet. It is usually of a light-blue or dove colour, and is often fine-grained and homogeneous. In the neighbourhood of Butler, and below New Brighton, it occurs as a bed of nodules ; but it still retains its usual thickness of three feet. This is its character also beyond the Ohio State line.

---

* See Conglomerate-band above the coals in the Castleman River section and the Indian Creek section.

Upper Freeport Coal.—This is an extremely variable bed of coal, being, as to this characteristic, the reverse of its companion, the limestone. On Beaver River it is often reduced to a mere trace a few inches thick, and then again it suddenly expands to a workable size, and becomes a useful bed of coal. Along the central line of the sixth basin it is often more than 4 feet thick, but it is never found to retain a given thickness for any great distance. Its coal is generally excellent.

The Barren Group.—Above the upper Freeport coal-bed lies a mass of sandstone of a homogeneous character towards the Beaver River country, but becoming a true conglomerate along the Mahoning Creeks. It may be a question for the curious, how far the variableness in thickness of the upper Freeport coal-bed may be attributable to the agencies concerned in making this deposit. This is the Mahoning Sandstone.

From Butler S.W. we fall in with yet higher measures : these increase in depth of material in that direction, in obedience to the regular slope of the basin. Above the small seam representing the Elk Lick Coal-bed are shales and slaty sandstones ; after passing Thorn Creek, yellow and greenish shales are seen to rest upon the latter. This is the red and variegated band which spreads so widely over the whole bituminous coal-field along the central lines of all the basins, wherever the land is high enough to take them in. At Pittsburg these have sunk nearly to the water-level. The gentle undulation of the fifth axis has caused their denudation along it ; but they occur again in the fifth basin, about 7 miles W. of Freeport, and stretch past Kittanning. Being soft and friable, they decompose into a clay, and often contain small nodules of limestone.

Upon the series of rocks last mentioned, and immediately overlying a variable seam of hard brilliant coal, from a few inches to a foot and a half thick, there is a thin, sandy, ferruginous, blue or brown limestone, abounding in fossils, and ranging widely through the basins. It occurs at Kittanning, everywhere on the Kiskiminetas and Mahoning creeks, where the basins are deep enough to receive it along their central lines, and is traceable as far N.E. as Clearfield Creek : in the latter neighbourhoods, however, the coal is wanting. At Karthaus, on the contrary, the coal seems to be present, and the limestone wanting. This limestone is found in most of the hills around Woodville, and may be seen upon the turnpike running S. from Butler, about half a mile from the bridge, and perhaps 50 feet from the summit of the hill. As the basin deepens toward the S.W., this bed occupies of course a wider area and a lower position upon the hill-sides : it is usually 1 or 2 feet in thickness, and above it are olive and blue slates.

The rest of the Barren Measures.—We have now arrived at that line or belt of outcrop which, as will appear by glancing at the map, divides the great bituminous field, with all its basins, E. and W., by a zone of land barren in coals, into two nearly equal parts. Before passing this zone to the S., and carrying on the description of the whole series of Coal-measures in its next subdivision, based upon the Pittsburg Coal-bed, to the S. line of the State, it will be proper to take advantage of the opportunity afforded to bring up the description of the first and second basins in their prolongations S. of the Conemaugh River.

SUBDIVISION II.

BITUMINOUS COAL-BASINS SOUTH OF THE CONEMAUGH AND OHIO.

The two most prominent features of the country S. of the Conemaugh River are the two anticlinal mountain ranges, Laurel Hill and Chestnut Ridge, the supposed prolongations S. of the highlands elevated by the first and second axis described in the preceding pages. Bringing up along their summits the Vespertine Sandstone, and supporting on their broad flanks the outcropping Lower Coal-measures, which N. of the Conemaugh arch over them, these two lines of elevation make the region susceptible of a threefold division, of which each part shall be considered in detail. The country between the Alleghany Mountain and Laurel Hill will be the first division: it is subdivided into three subordinate basins. The second division lies between the great mountain axes. The third stretches from the Chestnut Ridge to the W. line of the State: this also includes several subordinate basins.

CHAPTER I.

THE FIRST COAL-BASIN AND ITS SUBDIVISIONS, OR THE SYNCLINAL BELT BETWEEN THE ALLEGHANY MOUNTAIN AND LAUREL HILL.

This wide tract of Coal-measures, descending from the W. summit of the Alleghany Mountain, and ascending the E. slope of Laurel Hill, is traversed lengthwise by two subordinate lines of anticlinal elevation. The first, which is the axis of Negro Mountain, issues from the State of Maryland, between the head-waters of Jones's Run and the waters of the Little Youghiogheny River, crosses Castleman's River below the mouth of Buffalo Lick Creek and Shade Creek, between Huskin's Run and Roaring Fork, and expires on the summit of the Alleghany Mountain, S. of the Portage Railroad. At this its Northern termination it is merely a broad and gentle swell or roll of the rocks; but retracing it S., we find it assuming a more decided character. It forms a line of hills, increasing in height as they pass within 2 or 3 miles of Stoyestown to the E., and at length becomes in Negro Mountain a bold and regular ridge. This, as the axis continues to rise gradually Southwards, parts at the State line into two slowly-diverging mountain-ranges, which continue their course towards the Potomac River.

The second sub-axis of this basin issues S. from the imperfectly explored country around Ebensburg, crosses the Conemaugh at the Railroad Viaduct, 8 miles E. of Johnstown, where it brings up the red shales of the Umbral series; thence ranges to Stony Creek, below the mouth of Paint Creek, and is last observed upon the Quemahoning, at the mouth of Roaring Run. In the general aspect of the country this sub-axis scarcely makes its presence known, except perhaps by a line of hills rather higher than the crests of those on either side of it.

Thus we have in the first basin, S. of the Conemaugh, three minor troughs; the Salisbury Trough to the S.E., the Johnstown Trough to the N.W., and the Stoyestown and Somerset Trough between the two. The Coal-measures along the whole course of the viaduct sub-axis, and along the line of the Negro Mountain sub-axis, as far S. as Somerset, pass over from one of these troughs to the other.

The First or Salisbury Subdivision.—In obedience to a general law in the conditions governing the undulations of the crust, while the sub-axis of Negro Mountain rises towards the S., the synclinal trough included between it and the Alleghany Mountain deepens in that direction. Hence the thickness of the Coal-measures at this N. end is inconsiderable, but increases rapidly Southward: at the head-waters of Stony Creek four coal-beds, as yet very little explored, give evidence of their existence throughout the neighbourhood, and three occur around Shanksville. The strata in the Alleghany Mountain generally dip to the W., at an angle varying from 15° to 20°, causing the overlying Coal-measures to ascend the W. slope to within 1½ miles of the E. crest.—(See General Section IX.)

Passing S. of Berlin the Coal-measures increase their total depth in the basin, and become at the mouth of Elk Lick Creek of sufficient thickness, not only to include all the barren measures above the Elk Lick Coal, but to take in also the Pittsburg Seam, with two other coal-beds, and a large limestone bed of the much higher Waynesburg series. The area of these is at first confined to a long and narrow strip of high land between Castleman's River and Elk Lick Creek, where they are parallel, and both run N. This strip of high land is here the central line of the sub-basin. By means of a salt boring on Elk Lick Creek, a section is obtained, which exhibits 400 feet of Coal-measures below the level of the creek; and the hill above described, capped by the limestone, furnishes about as much above.—(See Sections at Elk Lick Creek and Elk Lick Salt Well.) The lower measures outcrop in a range of hills along each side of the basin, on the flanks of Negro Mountain and the Alleghany Mountain.

Of the Clarion group, three beds, one 3 feet, another 6 feet, and a third 3 feet 3 inches in thickness, are traceable here. The lowest and smallest one is either the Clarion or Brookville Coal. The next is the Ferriferous Coal-bed, underlaid by its limestone, 5 feet thick. This limestone is well developed at the mouth of Buffalo Lick Creek, overlaid by its appropriate ore-stratum, 2 feet in thickness. The third, 25 feet above the last, is the Kittanning Coal. Separated by an interval of 160 feet from the Ferriferous Coal below, we find, ascending to the Freeport group, the Freeport limestone, 5 feet, and Upper Freeport Coal, 2 feet thick. In the upper part of this interval, from 20 to 30 feet below the limestone, is the Lower Freeport Coal-bed. 50 feet above the limestone is the Elk Lick Creek Coal-bed,—here, as everywhere along the S.E. Barrens, a bed of considerable size, being 4 feet thick, and having sometimes, 10 feet underneath it, a nameless 1-foot bed of coal.

More than 150 feet of barren measures intervene between the Elk Lick and Pittsburg Coal-beds. In this group of barren measures occur two very small coal-beds, and a limestone above the uppermost 1½ feet thick.

Above the Pittsburg Coal-Seam, at intervals of 40 and 50 feet, are the outcrops of two coal-beds belonging to the Waynesburg group, and named after the places where they attain their maximum persistent thickness, the Sewickley and the Uniontown Coal-beds. Their exact thickness here is unknown, but the lower one is judged from the aspect of its outcrop to be a large seam: both occupy an area more confined than that covered by the Pittsburg Seam below them, their N. limit being in the narrow ridge before described, between Elk Lick Creek and Castleman's River. The top of this ridge is capped by a massive bed of limestone. These are the highest rocks in this first sub-basin, and are traceable S. in connection with the Pittsburg Seam into Maryland.

The iron ore over the Ferriferous Coal-bed is finely exposed at the falls on Elk Lick Creek. It here appears in three layers, the lowest affording 16 inches of solid ore. It makes its appearance also on other branches of the same creek; and is the same ore-stratum that is wrought in the second basin at Fayette Furnace, Ligonier Valley, and appears on Four-mile Run. It may also be hereafter identified with the abundant deposit of ore discovered on Shade Creek towards Johnstown, 10 or 15 feet beneath a 16-inch coal-seam, the Kittanning (?) Coal; and also at Lambert's Mill, where the ore is more disseminated in a bed of dark shale overlying a 3½ feet coal-bed, doubtless the Ferriferous Coal, with its limestone underneath, 2 feet in thickness.

The Second or Stoyestown Subdivision.—This subdivision of the first basin ranges N. into the Mount Pleasant and Philipsburg Coal-field, and at the S. unites, by the dying-out of the viaduct axis, with the third or Johnstown subdivision, in the latitude of Somerset.

Along the Conemaugh, which crosses it obliquely, its rocks are frequently exposed in perpendicular escarpments, affording fine vertical sections. At and near the summit of the Portage Railroad, the Clarion and Freeport groups of coal strata are developed, their E. outcrops ranging along the summit of the Alleghany Mountain. Three or perhaps four workable seams are among them, ranging from 2 to 5 feet in thickness. The Freeport limestone appears, and probably the Ferriferous limestone may also be found. A coal-seam of the Tionesta group has been recognised in a 9-inch bed, 10 feet above the conglomerate. It is to be understood that the names affixed to the several strata of coal and limestone are not the results of absolute identification of the beds, but are only to be regarded as the nearest approximations that can be made in the present state of development.

The limestones exposed on the Conemaugh vary in thickness from 3 to 10 feet, and at Johnstown the Ferriferous limestone is in part a cement, or hydraulic limestone. Higher in the hills at Johnstown two other bands of limestone occur, immediately below the uppermost of which reposes the valuable stratum of calcareous iron-ore so extensively mined at that place.

The representative of the Kittanning Coal seems to be small in this region, frequently not measuring more than 9 inches.

Besides the two small known beds of limestone there seems to be a third calcareous stratum, from 3 to 6 feet thick, claiming a position beneath the Lower Freeport Coal. It makes its appearance in two localities on Stony Creek—viz. at the Red Bridge and 5 miles S.E. of Johnstown. On Stony Creek, half a mile below the

Red Bridge, a limestone bed and bed of iron ore are observed together, 30 feet above the Ferriferous coal; an ore-stratum also exists on the old planes Nos. 2 and 3. The relation of these to the other beds of the series is at present so vague as not to warrant any strong assertion: each should be made a matter of further investigation.

Along the central parts of the trough two coal-seams occur in the barren measures below the Pittsburg Coal-beds. One of these was found to be 1½ feet thick.

Tracing this second subdivision of the first basin S. from the Conemaugh, there appears but little change in the series of rocks. Regarding the double seam of the Alleghany summit as one coal-bed, subdivided by an unusual thickness of shale, we find the vertical distance between the lowest coal-beds increases from 80 (?) feet to 100 at Stoyestown, and 130 feet at Salisbury. The Lower Freeport Coal is mined 4 feet thick at Stoyestown. The Upper Freeport Coal seems here to present the unusual aspect of two beds, each 3 feet thick, and 8 feet asunder: 90 feet above it is seen the outcrop of the Elk Lick Coal; and between that and the tops of the highest hills are two or three small seams.

By the rapid rise of the Negro Mountain axis, this middle trough is made so shallow, in approaching Somerset, as to contain but little coal in the neighbourhood of that town.

The Third or Johnstown Subdivision.—The series of rocks given above is substantially valid for the Western Subdivision of the first basin, along the E. flank of Laurel Hill and in the neighbourhood of Johnstown. Upon the summit of the mountain the Umbral red shales appear, while on its flanks repose the strata of the Seral conglomerate dipping rarely more than 7°.—(See General Section No. IX.) Between these two formations is the position for the Sharon Coal Group, first seen in the neighbourhood of the Stoyestown Turnpike, where it crosses Laurel Hill. Here the group is about 30 feet thick, and contains one bed of solid coal 9 inches thick, immediately underlying the conglomerate, as in the Sixth Basin. Traced 10 or 15 miles further towards the S., this bed becomes 2½ feet thick, and overlies the Umbral ore by an interval of 30 feet. This group continues to exhibit increasing thickness and richness of mineral contents in this direction until it disappears across the line into Virginia.

The Seral conglomerate along the E. flank of Laurel Hill is very variable. Upon the Conemaugh it is a coarse sandstone about 60 feet in depth; while W. of Somerset it shows but 30 feet. It, however, increases to upwards of 100 feet upon the Youghiogheny River.

Upon this conglomerate reposes, in all the country S. of the Conemaugh, a mass of sandstone strata, Tionesta Sandstone, &c., varying in thickness, character, and consistency, but always strongly marking the position of the lower Clarion Coal-measures, not merely geologically, but topographically also, by lines of high, steep, broken hills ranging along the base or flanks of the two anticlinal mountains, Laurel Hill and Chestnut Ridge. These hills will be described more in detail when we reach the first sub-basin of the country W. of Chestnut Ridge.

Shut up between these massive sandstone layers are the coal-beds of the Clarion and Freeport Groups. The Tionesta Group, on the contrary, seems to have representatives among them; and, as was before remarked in describing the Alleghany summit section, one of the coal-beds has thinned away so as to be barely noticeable.

The lowermost coal-bed, whether receiving the name of Brookville Coal or Clarion Coal, is at the Portage Railroad 5 feet thick, and at Johnstown 3½ feet, becoming thinner towards the S. We have seen it to be 3 feet thick in the S. part of the Salisbury subdivision, but on the W. side of Negro Mountain, along Castleman's River, it is but about 2 feet, and where it rises upon the side of Laurel Hill it varies from 3½ feet even down to 1 foot.

The Ferriferous coal-bed is the next above; it is divided from the preceding bed by an interval of about 70 feet, part of which consists of a massive stratum of brown sandstone, which in the Second Basin will be seen to become almost indistinguishable from the Seral conglomerate below. The Ferriferous limestone is present also underlying the coal. On Ben's Creek their respective thicknesses are, limestone 3 feet, coal 4 feet. But so variable are they in this respect, that at Milford their dimensions are, limestone 4 feet thick, and coal 1 foot; and on Castleman's River, limestone 8 feet, and coal 4 feet. Besides this, the character of the limestone does not persist, becoming, as a striking instance, in the distance of a few yards along the Johnstown and Somerset Turnpike, a bed of carbonate of iron.

The Kittanning coal-bed apparently maintains a uniform distance of 25 feet above the last throughout the first and second subdivisions of the First Basin with considerable regularity, being 25 feet above it on the E. flank of Negro Mountain, and 30 feet above it along Castleman's River, W. of that ridge. Disregarding the Johnstown section, where the facts seem at variance with our observations at other localities, we find that along Laurel Hill the interval between the beds averages 50 feet. The rocks of this interval have everywhere a decided tendency to a shaly structure; and at the lowest limit of this shaly mass is to be found the iron ore which accompanies the Ferriferous Coal. The Kittanning Coal-bed, which appears as a very thin seam at Johnstown, exhibits an increased thickness of 4 feet at many places along the E. flank of Laurel Hill, but towards Negro Mountain, on Castleman's River, it is again but 2½ feet thick.

The Lower Freeport Coal maintains a thickness of 4 feet along Laurel Hill Creek; but on Castleman's River it could nowhere be recognised. It seems to thin out locally in that direction, since in the Salisbury Section (See Column, Chapter XXIX.) it is only marked, if at all, by a thin seam 25 feet beneath the Freeport Limestone.

Along the Conemaugh and Laurel Hill Creek this bed lies at a distance of 20 or 30 feet above the Kittanning Coal (See Column, Chapter XXIX.), and is shut in by massive sandstone strata, the representatives of the Freeport Sandstone. This divisional rock appears, however, throughout this region rather to be above than below the Lower Freeport Coal-bed. The abundance of sandstone between the Kittanning and Upper Freeport Coal-beds is very manifest, and may in part explain the imperfect exposure, or perhaps the actual thinness, of the included Lower Freeport Coal-bed, at the S.E. portion of this First Basin. Where the interval is small, the latter bed appears as along the Laurel Hill; but where the interval is great (105 feet in the Salisbury Subdivision of the First Basin, and 100 feet in the Second Basin), on either side of this central line the coal-bed escapes observation.

The Freeport Limestone does not appear in the Johnstown Section in connection with what we have chosen to regard as the Upper Freeport Coal. It may not have been discovered, as the beds elsewhere range in close proximity through this subdivision of the First Basin, maintaining a position about 40 feet above the Lower Freeport Coal where the latter is present. The coal-bed averages 2 feet on Castleman's River, and nearly 4 feet on the Conemaugh, in the few localities where it has been discovered. The limestone stratum probably never exceeds a thickness of 3 feet.

Above the beds last mentioned, the Mahoning Sandstone spreads with little interruption, forming the top stratum of the Freeport Group, and supporting at Johnstown the great ore-stratum and the Elk Lick Coal. The barren measures compose all the hill country along the middle of the synclinal trough. Proceeding S., these measures thicken and the hills grow higher, but never so as to take into their summits the Pittsburg Coal-seam as in the first or Salisbury subdivision. They exhibit upon their sides in the neighbourhood of the Turkey Foot, or junction of the three branches of the Youghiogheny, the most beautiful series of terraces formed by the successive and horizontal, soft and hard strata of coal, slate, and sandstone, among which are the Elk Lick Coal and the two minor seams above it. If the Pittsburg seam enters our State at all in this subdivision of the First Basin, it must be for only a very small distance N. of the Maryland line. There is a bare possibility of its existence in the N. part of the central line near the Conemaugh, S. of Johnstown, where, throughout a range of several miles, a conspicuous coal-bench is visible at many points upon the very highest land and in a position agreeing with that which this important bed ought to occupy, adopting the Ligonier Section of the next basin as a standard of measurement.

CHAPTER II.

THE SECOND COAL-BASIN; OR LIGONIER VALLEY.

Topographically, this is the best-defined basin in the bituminous coal region—simple and symmetrical—and having on each side of it a long and regular mountain. The synclinal axis of the trough coincides with the central line of the valley.

The reader must not allow himself to be perplexed by a singular transference of the names of the two bounding ridges, after passing to the S. side of the Youghiogheny. In Virginia the Western Ridge is called Laurel Hill, and the Eastern, Chestnut Ridge. We shall always speak of them as they are known in Pennsylvania.

Seldom rising to a greater height above the valley than 900 feet, and resting on a base from 3 to 5 miles wide, these mountains are broad and regular swells, deeply cut on either side by the head-waters of streams which descend at right angles from their axis-lines. The Vespertine sandstone crowns the broad arch along the level back of each, and is overlapped on each flank by the Umbral red shales, and these again by the Seral conglomerate. Sometimes, however, this last formation has more successfully resisted the ancient denudation, and rides over all, arching the axis, and standing up in humps along the summit of the mountain.

The central parts of the basin are occupied by the barren measures, capped in one locality between the Conemaugh and Loyalhanna by the Pittsburg coal-bed and the still superior Waynesburg Coal group. On each side of the Barren Measures, first the Freeport and then the Clarion group of coal and limestone beds, enclosed in massive layers of sandstone, rise upon the inner flank of either mountain, and contrast in a marked manner with the shaly system of the middle range of hills composed of Barren Measures. These lower sandstone strata, outcropping E. and W., present their high, steep, and ragged lines of isolated hills towards the foot of either mountain, or even invade half the height of its gently-sloping side: they rest upon the Seral conglomerate.—(See General Section IX.)

Where the mountains are cleft by such streams as the Youghiogheny, Loyalhanna, and Conemaugh, the top rocks of the Vergent series, which never rise very high above the water-level, appear at the axis or crown of the arch.

The coal-basin maintains a very uniform width of 6 or 7 miles. The dip of the rocks seldom exceeds 7°, except along the E. edge, or rather in the lower slope of Laurel Hill, where, in some places near the Youghiogheny, it amounts even to 30°. In the centre of the basin the rocks are nearly horizontal, and deeply trenched into numerous subordinate valleys.

Along the Conemaugh are exposed the beds of the Clarion group and of the Freeport group above it; and here also the Brookville and Clarion coals are represented by one double bed, varying from 3 to 5½ feet in thickness.

The Ferriferous Coal, next in order ascending, is 22 inches in thickness, underlaid by its limestone 3 feet thick. In one locality 8 inches of this is hydraulic lime.

The Kittanning Coal is not observable. The lower Freeport Coal is from 2 to 3½ feet thick, and is underlaid by limestone; and the Upper Freeport Coal, with 3 feet of impure limestone underneath it, is from 5 to 6 feet thick.

These are all included within 160 feet of strata, so that all the intervals are near their minimum of thickness. But as we proceed Southward they become greatly enlarged, so that at the mouth of Indian Creek, upon the Youghiogheny, the same series of rocks are found to occupy a vertical space of 260 feet. There the Ferriferous Coal has expanded to 4½ feet, and the Lower Freeport Coal has disappeared. The Ferriferous Limestone, also, has increased in thickness to 8 feet; 15 feet above the coal is a workable band of iron ore.—(See Section on Indian Creek, Chapter XXIX.)

In the Barren Measures which everywhere form the central mass of the basin, are two small seams of coal.—(See Column at Ligonier, Chapter XXIX.) The upper one has a small bed of limestone, 1½ feet thick, resting upon it; this is doubtless referable to the position occupied by a limestone of about equal thickness, mentioned in the suite of beds in the first subdivision of the First Basin, as occurring 60 feet beneath the Pittsburg Coal-bed.

Between the Loyalhanna and Conemaugh, and along the exact centre of the basin, runs a high but very narrow hill, dividing, as it were, the valley into two. On each side of this long hill, and horizontally stratified through it, there crops out the great Pittsburg Coal-seam, from 7 to 10 feet thick. It is a mere reduplication of the appearances presented by the similar narrow bed between the Elk Lick Creek and Castleman's River, described in treating of the first subdivision of the First Basin.

Twenty feet beneath the Pittsburg Bed runs the outcrop of a limestone seam from 3 to 9 feet thick; and 25 feet below the latter may be seen the outcrop of a coal-bed 3 feet thick; and 8 feet under this another limestone, 3 feet thick. The appearance of these calcareous strata underneath the Pittsburg Seam is indicative of a law that the calcareous depositions increase towards the W., both the number and the thickness of the individual beds augmenting in that direction. We shall see the same fact hold good of the Limestone Strata of the Waynesburg Group, above the Pittsburg Seam.

At the summit of the hill above described are the same two superior beds of the Salisbury Section (see Column for Elk Lick Creek, Chapter XXIX.), the Sewickly Coal and Uniontown Coal, each 3 feet thick, but not separated by so wide an interval as in the former instance, and including between them a new limestone bed, 4 feet in thickness. Forty feet above the upper of these coal-beds is seen the highest limestone of the Salisbury Section, here 7 feet thick.

South of the Youghiogheny detailed examinations are yet required, but those made led to the belief that no material change of type in the series of strata presents itself. Here, as in the southern part of the First Basin, along Laurel Hill Creek, and further South, we find the rocks of the Sharon Group beginning to develop themselves: they contain at Stewart's Furnace a coal-bed 4 feet thick. This bed of coal underlies by 20 feet the bed of ore, which there, as elsewhere, marks the plane of separation between the Seral conglomerate and the Umbral Red Shales below it.

In this southern extremity of the Second Basin, the Ferriferous Coal appears 3 feet thick; 30 feet above it, the Kittanning Coal, 3 feet 2 inches thick; and 25 feet higher still, the undeveloped outcrop of the Lower Freeport Coal-bed.

CHAPTER III.

THE THIRD BASIN AND ITS SUBDIVISIONS, BEING THE REGION W. OF CHESTNUT RIDGE, AND S. OF THE CONEMAUGH AND OHIO.

THE region now to be described presents great uniformity of topographical aspect; its denudation is deep and irregular, and its whole surface a continued series of hills in no one defined range. Large streams, such as the Conemaugh, the Loyalhanna, the Sewickly, the Youghiogheny, Jacob's Creek, Redstone Creek, and the Monongahela River, meander through extensive valleys, and the upper waters of their innumerable side-streams are interlocked, and cover the land with a meshwork of hill and valley that bids defiance to precise description. The few marked features that present themselves amid this general uniformity will be noticed in their places.

The strata descending W. from the axis of Chestnut Ridge undulate gently over the crests of three parallel lines of anticlinal elevation, between that axis and the Ohio River at Pittsburg. These lines of elevation do not declare themselves by very positive features in the topography. Indeed, even a geologist might traverse the district, and would scarcely suspect, except at a few places, from surface indications alone, that there were such lines of elevation crossing the country upon which he looked. They are, however, occasionally marked in the general landscape as seen from some favourable points; seldom, indeed, as distinct ridges with regular declensions either way from continuous central lines or axes, but as ranges of hills distinguishable from the multitude of other hills in the synclinal troughs merely by a somewhat superior altitude and a marked sterility of soil. The first two of these lines of elevation are to be considered as sub-axes of the Third Basin; the other, or Westernmost, as the prolongation of its Western boundary, the third axis.

The first sub-axis of the Third Basin crosses the Conemaugh about 5 miles below the axis of Chestnut Ridge, and, running very regularly parallel with the latter, crosses the Monongahela below the mouth of Cheat River. There it shows a very gently-curving arch, having flattened very much from the point where it crosses the Redstone Creek. Its course is not precisely parallel with the axis of Chestnut Ridge as it gradually but very slowly diverges from it Southward, so that upon the National Road the interval between them has increased from 5 to 7¼ miles. Thence it maintains this interval to the Virginia line. It forms Brush Ridge.

The second sub-axis of the Third Basin crosses the Conemaugh, or Kiskiminetas River, about 5 miles W. of the first, and about 4 miles above Saltzburg; and runs S. parallel with it until within 1½ miles of the Big Sewickly, where it can no longer be observed to affect the strata. It resembles the first sub-axis in every particular, sometimes clearly marked by higher hills, sometimes obscure. It seems not to have suffered so much from denuding agencies as the other, excepting at its S. termination, where it is greatly abraded.

It is everywhere to be distinguishable to the least observant eye, by the marked barrenness of the soil under which it passes; which is due to the uplifting along its line of the coarse sandstone strata of the Clarion and Freeport Groups.—(See General Section IX.)

The third axis crosses the Kiskiminetas 4½ miles above Warren, but rapidly declines, and in a few miles disappears; as does also the fourth axis, which crosses the Kiskiminetas below Leechburg. The influence of these two axes may be regarded as active in producing the wide horizontality of the rocks throughout the region around Pittsburg.

First Subdivision of the Third Basin.—To obtain a general view of the Coal-measures overspreading the country to the W., a few words respecting them, as they repose upon the W. slope of Chestnut Ridge, will be sufficient. The Chestnut Ridge is denuded, more or less deeply, along the whole of its course from N. to S., by the small creeks or brooks which carry off the water that falls upon its broad summit; these flow down into the basin at its foot, turning at right angles, and running along its base, either S. or N., towards the nearest larger stream. In the ravines of a few of the runs even the Umbral Red Shales appear; in others, the lowest rock exposed is the Seral conglomerate; but in those midway between the larger streams, and where denudation has acted with least energy, even the lowest Coal-measures are not brought up to the day; but their outcrops must be sought high up the side and near the top of the Ridge.

As little success was here met with in attempting to identify and trace distinctly the various beds of the Clarion and Brookville Groups, with the coals below them, as observed and described in the N.W. outcropping of the Coal-measures, that classification will not be carefully observed in the following description of the geology of this region, but the whole series of rocks will be thrown into three groups, an arrangement which will not interfere with the former.

The Lower Group will include the Freeport and Clarion Groups of our previous classification, up to the Mahoning Sandstone. Its strata are chiefly massive sandstones. Lying as they do just upon the conglomerate, which itself forms the side and often the top of the Ridge, they possess a strongly-marked topographical character of their own, and, where denudation has not been too energetic, form a uniform terrace along the side of the ridge: elsewhere, a range of high, pointed, rugged hills, which at the entrances of gaps, such as the Gap of the Youghiogheny at Connellsville, become most prominent objects in the natural scenery of the country. But as these sandstones are not persistent in character, and are often interstratified with soft rocks, such as shales or slates, the single range of these hills is sometimes repeated, another range lying inside of the first towards the middle of the basin: between the two flow the little streams which have issued from the ravines of the mountain. Upon the terrace, or upon the sides of the ranges of hills, the lower Coal-beds outcrop; but generally the upper part of the interior or W. range of hills is composed of the middle group, sometimes even the large Pittsburg Coal-bed appearing at the summit.

The Middle or Barren Group is composed chiefly of shales, with one or two massive bands of sandstone in the middle and lower part. These latter, riding over the small axis to the W., cause the characteristic barrenness of the country traversed by them, which has been already mentioned. The group contains three Coal-beds, the Elk Lick and two superior beds, to which, in this region, have been assigned the names of the Barren Coal and the Little Pittsburg Coal. Whether the imperfect identification of these with the two superior small coal-seams of the Barren measures, in the first subdivision of the First Basin and in the Second Basin, will justify the application of these names to those also, is left to future observers to determine. Besides these, one or two thin seams occur which are not classified at present. The whole thickness of this group of rocks seems to be surprisingly uniform along the Chestnut Ridge. The interval between the Upper Freeport Coal at the base and the Pittsburg Coal at the top varies only from 600 feet in the N. part of the basin to 700 feet in the S.*

The Upper Group, based upon the great Pittsburg Seam, and including the Waynesburg Series, occupies the centre of the trough, and is characterised by an enormous development of limestone strata in its lower part, and the frequent occurrence of calcareous rocks throughout, as well as by the number and importance of its coal-beds towards the bottom of the series. Where the basin is deepest, this group measures 500 feet in vertical thickness, and contains 5 identifiable coal-seams—the Pittsburg, the Redstone, the Sewickly, the Uniontown, and the Waynesburg Beds—with several not yet classified.

---

* In the Morgantown Section, given in the Virginia Geological Report for 1840, the interval is 525 feet.

Lower or Clarion and Freeport Group.—The Seral conglomerate upon which this group is based is apparently but a few feet thick where brought up by the second axis in the Gap of the Conemaugh. At the Gap of the Youghiogheny it exhibits quite a vertical section of 70 feet, and of 60 feet at the Virginia State line. As exposed upon Dunbar Creek, it exhibits a mass of curled and twisted strata 100 feet in thickness.

Beneath it, one small coal-bed—that of the Sharon Group—6 inches thick, makes its appearance on Dunbar Creek, in connection with the valuable iron-ore of the Umbral Red Shales. The same is seen upon the National Turnpike, where it ascends the ridge.

Although abundantly sufficient data have been collected to establish the main points of identity of this group of coal-bearing strata above the Seral conglomerate, as a group, and to prove the persistency of their general features, as found in the more northern parts of the great Bituminous Coal-field, yet great difficulty has been experienced in tracing the individual beds of coal in the district before us. Their dividing sandstones form an almost uninterrupted continuation upward of the Seral conglomerate, the debris of which covers up their outcrops, thin as they generally are, along the ravines, and conceals, in like manner, their best indices, the limestone bands, by which we have traced them throughout the region already described; while the presence of the more available coal-seams of the Waynesburg Group, nowhere more distant than a mile or two, and easily opened on the sides of their hills of shale, has withdrawn inducements which the inhabitants would otherwise have felt to develop these lower coals.

The lowest coal-bed—the Brookville or Clarion Coal—immediately overlies the Seral conglomerate. Towards the N. it is of considerable thickness, but thins as we trace it S. In the Gap of the Conemaugh it is 4 feet thick; in that of the Loyalhanna, 5½ feet; at Morgantown, in Virginia, it averages 2 feet.*

The Ferriferous Coal-bed at the Gap of the Conemaugh is between 5 and 6 feet thick; beneath it is its limestone, 2 feet thick. At a point N. of the Youghiogheny River it was observed again, under a thin calcareous stratum, having a thickness of 2 feet. At this locality a band of nodular iron-ore occurs, 30 feet below the coal, which corresponds with a similar band of iron-ore in the first basin, exhibited in a section taken along Laurel Hill Creek.

The Lower Freeport Coal has been found as difficult to trace throughout this basin as the coal-beds underneath it. Everywhere along the side of Chestnut Ridge two coal-beds may be seen, separated by an interval of sandstone strata from 50 to 100 feet in thickness; the interval apparently increases S. and N. towards the heads of Jacob's Creek: these are the Upper and Lower Freeport Coal-beds. The Freeport Limestone was occasionally seen between them, in the sections made along the State line. The Lower Coal-bed averages 2 feet in thickness, but attains a thickness of 3 feet on Jacob's Creek. On the Loyalhanna, on the E. side of the first sub-axis, it is 2½ feet thick.

The Upper Freeport Coal-bed has an average thickness of 4 feet, and is almost everywhere a double bed. In the vertical section made at Morgantown, Virginia, it seems to be represented by two beds, 12 feet asunder. It is subject, however, to the most remarkable irregularities, varying at one spot, on the Big Sewickly, at the first sub-axis, from a thickness of 18 inches to 5 feet in a short distance; and at another locality, from one bed 3 feet thick, to two beds each 3 feet in thickness. At one place upon the Big Sewickly Creek it measures 9 feet of coal, confused under a wrinkled roof; at other places, it is known to thin away entirely. On Jacob's Creek it varies from slate containing but a few inches of coal, to a bed of coal 4 feet thick, with very little admixture of slate. The coal is usually good, even when its solidity is impaired. This is the coal-bed that affords, at so many spots along the Sewickly, the Loyalhanna, and at Saltzburg, the fuel for numerous salt-works.

---

* This bed is probably the one struck by a Salt-boring on the Big Sewickly, in the second subdivision of the Third Basin, 3½ feet in thickness, and 150 feet below the Upper Freeport Coal. At the Redstone, also, it appears about 180 feet beneath the Upper Freeport Coal; but it is there only 2½ feet thick. Beyond this, W., it has not been recognised. It is possible that this may be the bed opened on Mount's Creek, above Connellsville, measuring 4 feet thick, the upper 2 feet of which were slaty coal.

Over this variable bed of coal is seen the Mahoning Sandstone stratum, a coarse-grained, massive rock, with a maximum thickness of 50 feet. It is finely displayed by the side of the first sub-axis, where the latter crosses the Loyalhanna opposite Blairsville, and in many other localities further S. It is generally of a grey colour, curled and twisted, a true contorted sandstone, full of stems and leaves, and exhibiting every mark of rapid deposition. It does not always immediately overlie the coal; for an intervening bed of slate, sometimes 6 or 8 feet thick, is very frequently present; and in one locality, if our identifications are correct, its thickness amounts to 55 feet: this occurs on the Loyalhanna.

The Freeport limestone occasionally shows itself in fragments on the surface, underneath the Upper Freeport Coal-bed. At the Gap of the Loyalhanna a calcareous stratum, 3 feet thick, occurs, 50 feet below, in what is there supposed to be the Upper Freeport Coal, and immediately over a coal-bed. Another calcareous stratum, 2½ feet thick, holds a similarly related position upon Jacob's Creek. The identification of the beds is rendered more doubtful still when the variation of the interval between these Upper and Lower Freeport Coal-beds is observed —an interval often filled by micaceous sandstones. On Jacob's Creek this interval is 43 feet, the Upper Freeport Coal being nearly 4 feet thick, and the Lower, 3 feet. On the Loyalhanna, at the first sub-axis, the interval is but 25 feet between the coal-beds, both measuring 2½ feet. At the Virginia line, the interval is 100 feet, the lower coal being 2 feet thick. At Connellsville, the same two-feet bed is 93 feet below the upper coal. It would therefore seem more than probable that the observations, obtained with great difficulty, have confounded in some sections the Kittanning and Lower Freeport Coal-beds.

This Lower Group is nowhere exposed to the surface S. of the Redstone upon the first sub-axis, nor S. of Loyalhanna upon the line of the second.

Middle or Barren Group.—No phenomenon in the geology of this region is more remarkable than the extraordinary discrepancy between the interval occupied by the Barren Measures in the Third Basin, and that which they fill in the first and second. In the Salisbury division of the First Basin, the vertical distance from the Upper Freeport Coal, through the Barren Measures to the Pittsburg Coal, is only 225 feet; in the Ligonier Valley or second basin (N. end), scarcely 200 feet; not 10 miles to the W. of this locality, where the latter measurements were made, and simply on the other side of the anticlinal axis of Chestnut Ridge, these strata swell to 600 feet in thickness, and that without any apparent increase in the number of economical beds of coal and limestone. The same Elk Lick Creek Barren Coal, and Little Pittsburg Coal, seem to reappear in their proper relative positions, but with a vastly enlarged thickness of interstratified rocks, and these almost wholly composed of immense deposits of argillaceous shales. Error of measurement seems precluded by the repetition of the Ligonier scale beyond Negro Mountain, and of the Saltzburg and Connellsville scale upon the Monogahela, and at Waynesburg, further W. Possibly the great difference in the thickness of the group may arise from there having been an anticlinal barrier already elevated in the sea bottom at the time of the deposition of the materials, causing the rate of this to vary on the two sides.

By a similar comparison of localities, on the two sides of this same axis, far to the N., at Karthaus and at Bennett's Branch, we notice a similar increase of thickness, not in this Middle Barren Group, but in the Lower Group, the rocks between the Upper Freeport and Ferriferous Coals.—(See Sections at Karthaus and Bennett's Branch, Chapters VIII. and IX.)

Midway in the interval of Barren Measures above described, and seemingly persistent throughout the region, is a small coal-bed, averaging 1½ feet thickness. It is of value as an index to the other constituents of the group. Above it rests, in many places, a massive bed of sandstone, supposed to be characteristic of this portion of the series; and in connection with this coal are the "green limestone layers," traced extensively on both sides of the Conemaugh and far to the N. At Saltzburg these are 340 feet below the Pittsburg Coal-seam.

The Elk Lick Coal, 80 feet below the former, in the section made along the Virginia line, is at that place 4 feet thick. It doubtless will be found to occur in a similar position in the series everywhere, the interval increasing perhaps towards the N.; but it must vary greatly in size, as it has been identified at only four localities, by its usual superior thickness to that of the other coals of the Barren Measures. It issues from the Conemaugh below Livermore, to ascend the second axis; is a 3-feet bed at the head of Jacob's Creek, and 4½ feet thick on the Youghiogheny, in the second subdivision of the basin. It is 4 feet in thickness at Lobizer's Mill on Jacob's Creek, and is there estimated to be 150 feet above the Upper Freeport Coal, for which, despite this great interval, it has more than once been mistaken; but the massive Mahoning Sandstone, which generally overlies the latter, and the abundance of yellow slates and sandstones about the former, will assist in distinguishing them.

The exact position in the series of this middle group to be assigned to a very extensively persistent stratum of red and variegated shales, has not been determined. We are inclined to place them above the sandstone over the Barren Coal-seam. In one locality on Jacob's Creek a fossiliferous limestone is seen at their upper limit, and over this again a stratum of calcareous nodules and ore. These, perhaps, appear upon the Loyalhanna, where the lower limestone is 6 feet thick, impure and weathering yellow; and the upper bed, 60 feet above the other, is 2 feet thick. An exposure of ore and red shale, overlying sandstone strata, somewhere in this part of the series, may be observed on Jacob's Creek, at Hess and Chair's Mill. It is pretty well ascertained that limestone is usually associated with this set of red-shale strata in the Barren Measures: it may be that more than one such occurs at different heights. The Red Shales appear in some sections just over the lower sandstones of the group; in others, not far below the "non-fossiliferous" limestone in its upper part. In the section at Morgantown, Virginia, they occupy a middle position.

The Barren group limestone, as it may be called, is a quite persistent calcareous member of this series, occurring above 150 feet beneath the Pittsburg Coal-seam, and 5, 4, and 3 feet thick respectively, as seen upon George's Creek, the Youghiogheny, and the Conemaugh.

A massive sandstone is observed with some irregularity at a distance below the Pittsburg Coal. It caps many of the hills along the first sub-axis between the Loyalhanna and Sewickly Creeks. It may be observed—70 feet in thickness—in the section made at Pittsburg, about 100 feet below the great seam.

Very small coal-seams are seen in parts of this group; one such is 14 inches thick on Jacob's Creek, and 100 feet above is a 6-inch seam. The same appears in the Morgantown section.

The Little Pittsburg Coal is a bed about 1½ feet thick not everywhere observed, and apparently thinning out towards the W., as it does not make its appearance in the Pittsburg and Waynesburg sections. An average of its variable depth below the Pittsburg Coal would be perhaps 100 feet. Upon the Youghiogheny a limestone lies below it mixed with shale from 4 to 12 feet thick. In the second basin, at Ligonier, this calcareous band is 3 feet thick.

The great limestone stratum at the top of this group properly belongs to the third or upper group, and will be described with the Pittsburg Seam.

THE UPPER OR GREENE COUNTY GROUP.

For a certain space beneath the great Pittsburg Coal-bed, the nominal base of the group, the strata are calcareous, with a tendency to the exhibition of massive limestone beds, even to one 25 feet in thickness, as at Pittsburg. In the Second Basin, near Ligonier, the lowest 5 or 10 feet of this space is a solid limestone stratum, separated by 20 feet of shales from the coal.

At Blairsville on the Conemaugh, at the first sub-axis of the Third Basin, the stratum measures 12 feet. In the Youghiogheny section, and in the Morgantown section, a coal-bed 1½ feet thick is associated with it.

The Pittsburg Coal-Bed, assumed as the base of the upper group, extends along the whole line of the first subdivision, from the Conemaugh to the Virginia State line, and outcrops to the right and left in the first range of hills facing the first sub-axis W., and in the second range of hills facing Chestnut Ridge E. Two miles to the S. of the National Road it arches over the line of the first sub-axis into the second trough or subdivision of the third basin. In the centre of the first trough the Pittsburg Coal-bed descends to within a few feet of the water-level of the Conemaugh, and then sweeps horizontally and ascends again. It appears beneath the water-level on the Loyalhanna for 2 miles, and upon the Youghiogheny for 1¼ miles. On the Sewickly its lowest point in the centre of its synclinal basin is estimated at 170 feet beneath the water-level. But on Jacob's Creek it does not descend to the stream.

The E. line of outcrop of the coal alternately approaches and recedes from Chestnut Ridge in obedience to an irregularly denuded surface, and in one instance to a small local axis upon Mount's Creek. The distance, therefore, from outcrop to outcrop—that is, the breadth of the area it covers—varies, being 1½ miles at New Derry in the N., but on the Youghiogheny only ¾ of a mile, and if measured straight across along the river, it is 1¼ miles. Approaching the State line it becomes nearly horizontal, and spreads over almost the whole area of country between George's Creek, the Monongahela River, Cheat River, and Chestnut Ridge. Its lowest approach to the water-level there is 173 feet; its highest elevation, 371 feet. In the second subdivision of the Third Basin, W. of the first sub-axis, it sinks again below the water-level in most of the water-courses S. of Jacob's Creek, rising again W. upon the Brownsville continuation of the second sub-axis. Upon the Youghiogheny River it enters the water 1 mile below the mouth of Jacob's Creek, and on the Redstone Creek, 300 yards below Sharpley's Mill, reappearing with an E. dip 1 mile above its mouth. In the third subdivision it comes up from the water-level with an E. dip, near the mouth of Sewickly Creek, and at the mouth of the Youghiogheny River is 25 feet above the stream.

The character of the Pittsburgh Coal-seam in all this region is well marked, showing everywhere a disposition to divide itself into a lower bed of solid coal, and an upper series of thin, alternated, often contorted, seams of coal and slate, in which sometimes the coal predominates, at other times the slate. The lower member is almost universally a good, pure, solid, columnar coal; though towards the Virginia line this also shows a disposition to become more slaty. It is usually free from sulphuret of iron, except along a strip of country lying W.N.W. and E.S.E. in the line of Cat Run, where large lumps of iron pyrites occur.

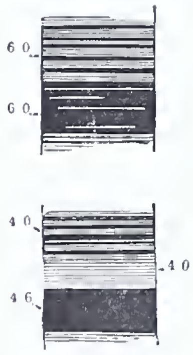


FIG. 332.

The thickness of the lower member of the Pittsburg Coal-bed is variable, being 6 feet thick on the Conemaugh, and from 7 to 8½ upon the Loyalhanna. The average thickness of the upper member is 3 or 4 feet; it is far more variable than the other. Sometimes it contains a coal-seam 12 or 15 inches thick, a foot above the lower member, and on this alternations 2 feet thick; and then the lower member is 7½ feet thick: this is in the second trough. At another place an interval of 2 feet of shales separates a coal-bed of 2 feet from the lower member. Again we find 4 feet of alternations, and between these and the lower member 2 feet of sandstone. This rock may indicate the true cause of the wide prevalence of the double character of the bed. Again, at Smythfield may be seen the accompanying Sections, made within 400 yards of each other.

Upon the Sewickly Creek the lower member is 9 feet in thickness; the upper one 5½, with a little slate intermixed. This makes the whole bed 14 feet thick, which is its thickness in the Waynesburg section.

We may consider its average thickness in this basin, 10 feet; in the second basin, 8½ feet; in the Salisbury subdivision of the first basin, 9 feet. Still further E., in the isolated basin of Savage Mountain, it may perhaps be recognised as the equivalent of a double bed of coal 7½ and 4 feet thick, overlaid at a distance of 90 feet by a seam 14 feet in thickness.

The ore at Savage Mountain occurs as bands of carbonate of iron nodules imbedded in shale below, between, and above the two members of the double coal-bed. In the Salisbury Basin, iron-ore is found below the Pittsburg Bed; the quality and quantity are unknown. At Oliphant's Furnace the ore is obtained under the coal; and the same ore is said to have been found at Mount Braddock, S.E. of Uniontown, in the same position; but it is nowhere wrought N. of Redstone Creek. It was not seen in the Ligonier Valley or Second Basin. It is certainly a question why it should range only S. of a particular line.

In the second trough or subdivision the Pittsburg Coal-bed extends in the shape of a canoe from a point a few miles to the N. of New Alexandria, on the Loyalhanna, to a point 3 miles S. of Greensburg. Over this area the rocks above this bed have no great vertical height. On the N. side of the Loyalhanna Valley the bed has escaped denudation only upon the W. side of the trough, and is there 8 feet thick, with its characteristic divisions.

The Pittsburg Sandstone.—The characteristic rock above the Pittsburg Coal-bed is a massive sandstone stratum irregularly stratified, weathering with roundish holes, and, where exposed along the Conemaugh and Loyalhanna streams, from 30 to 50 feet in thickness. It is a rock with variable aspect, but the interval between the Pittsburg Coal and the next bed above is a sandstone interval. It appears—25 feet thick—in Greene County and at Pittsburg, and 40 feet in the Salisbury trough of the First Basin. It forms " the Barrens " near New Derry in the N. part of the first trough of the Third Basin. A few feet of shales usually prevent this sandstone from resting immediately upon the upper member of the Pittsburg Coal-bed ; and these shales sometimes attain a thickness of 20 feet. In some few instances, as at Wheeling, the sandstone stratum is wholly wanting, its place being supplied by more argillaceous or calcareous rocks.

The Redstone Coal.—In the Salisbury Basin (Column of strata at Elk Lick Creek, Chapter XXIX.) the outcrop of a large coal-bed is marked 40 feet above the outcrop of the Pittsburg Coal. In the Ligonier Valley a 3-feet bed of coal occurs at half that height. In the Third Basin, on Redstone Creek, and at Mount Braddock, to the S.E. of Connellsville, a coal-bed, varying from 2 to 3½ feet, the smut at the outcrop of which is occasionally seen to the N., but not to the S. of the Redstone, has been opened at a height of 45 or 50 feet above the Pittsburg Coal-bed. At Mount Braddock the coal is interlaid with slate. In Virginia the same bed is traceable, from 3 to 4 feet in thickness in the neighbourhood of Morgantown ; but at Wheeling it presents an outcrop of only 5 inches.

The Sewickly Coal.—The next coal-seam in the ascending order is to be found at an average height of 100 feet above the Pittsburg Seam, and in two instances it is enclosed between two layers of the Great Limestone. The average thickness it exhibits may be stated at 4½ feet, though it ranges in places from 1½ to 5½ feet. It measures 3 feet in the Ligonier Section of the Second Basin, and 5½ feet in the Virginia Section at Morgantown. At Wheeling it is scarcely visible.

In tracing this Sewickly Coal-bed, and the one below it, the Redstone Coal, beyond the Alleghany Mountain, over into the Savage-Mountain Basin, one can only refer to the two coal-beds there exhibited as 12 feet apart, the upper one measuring 5½ and the lower 14 feet in thickness, and at a proper elevation of 90 feet above the double Pittsburg Vein. The great thickness of the lower bed is the most striking feature in this analysis of identity. As the Redstone Coal thins away Westward to almost nothing at Wheeling, there is a probability of its thickening Eastward even to 14 feet in this outlying basin. It may be observed here that the ore-bearing shale beneath the lower 14-feet bed, has its representative in the section made at Uniontown beneath the Redstone Coal. As to their close approximation in the Savage-Mountain Basin, the same is true of them at Wheeling, where they have reached extreme tenuity, and are but 24 feet asunder. In conclusion, it is proper to say, that the rocks of this upper group, although denuded from over such extensive areas, and having therefore many links deficient in the chain of their exposures across the country, furnish sufficiently ample data to establish results which would have been regarded but a few years back as quite chimerical.

The Sewickly Coal-bed is first seen as we trace it S. from the Conemaugh, W. of the Chestnut Ridge, upon Sewickly Creek. It is here nearly 5 feet thick, with 20 feet of dark-blue and brownish shales above.

Near Uniontown there rests upon it a curled and twisted sandstone, full of wedges and chips of coal ; it has usually limestone over it. At Mount Braddock it is 4 feet thick ; but on the Youghiogheny only 15 inches. To the S. of George's Creek it is much swept away, although it occurs even S. of Cheat River. To the S.W. of Redstone Creek it has been opened in several localities, and is 4 feet thick.

In the second sub-basin it is not found at Greensburg, but on the Big Sewickly Creek, not far distant, it is observed. It rises from the water of the creek at a point three miles below Markle's Mill, with E. dip. The Pittsburg Coal rises at a point one mile lower down the creek, or two miles above the creek's mouth.

The Great Limestone-Bed.—This is a series of alternate calcareous and argillaceous strata, varying in thickness and composition, the whole mass being of greater or less compass in section, according to the upper limit assigned to it. Upon the Monongahela, in the neighbourhood of Pittsburg, its thickness is estimated at 60 or 70 feet, enclosing the Sewickly Coal-bed, and extending upwards to a seam of coal. The Uniontown Coal is 1 foot thick ; a calcareous stratum 8 feet in thickness, which may be thrown into the general mass, occurs 25 feet still higher than this coal, and with that the limestone deposits in the section seem to cease.

At Wheeling the expansion of these strata is enormous; the deposition of calcareous matter, commencing immediately above the Pittsburg Coal, has been continued with slight interruptions, and some admixture of argillaceous ingredients, for a vertical height of about 260 feet, of which 160 feet of technically solid limestone may be seen. Two small beds of coal in the lower part, and a third in its upper limit, subdivide this vast deposit. In the neighbourhood of Waynesburg, in Greene County, these coal-seams do not appear in the section, but the calcareous deposit is exposed in three coherent layers, the lowermost 16 feet thick; then, after an interval, 31 feet of shales, the middle band 18 feet thick; and after another interval of 40 feet, the uppermost (corresponding to the 8-feet limestone in the Pittsburg Section) 8 feet thick.

Upon the Sewickly Creek in the third sub-basin there is one great deposit of limestone 70 feet in thickness, and four smaller ones, measuring in the aggregate 40 feet. Upon the Youghiogheny it is divided by the plane of the Sewickly Coal-bed, 24 feet of limestone underlying the coal, and 22 feet of limestone overlying it; while more than 50 feet of calcareous argillaceous alternations occur above the upper member. At the broad ford of the Youghiogheny, it is exposed in two beds 50 feet asunder: the upper bed is 40 feet, the lower one 35 feet in thickness. It wears a similar aspect in the Virginia section at Morgantown, where it is also divided into two beds 50 and 8 feet in thickness, the Sewickly and Redstone coal-beds occurring in the interval. This appears to be its type where perfectly developed, but it is subject to amazing changes: it thickens and consolidates remarkably when traced towards the Youghiogheny River, not presenting an equal thickness, even at points so near as the exposures upon Jacob's Creek. It is finely exposed upon Mill Creek, south of the Youghiogheny River.

Upon the Redstone Creek the limestone exhibits one great belt 67 feet thick, and many smaller bands above. Traced S. from the Youghiogheny, the strata rising with the Basin, this limestone caps the highest hills. To the S. of George's Creek, perhaps only the lowest member enters the highest summits. It forms a high narrow wall-like ridge between the Youghiogheny and Mount's Creek. Traced E., we see the Great Limestone represented in the Ligonier Section of the Second Basin, by one bed 4 feet thick beneath, and another a 7-feet bed, 30 or 40 feet above the Sewickly Coal. While in the Salisbury trough of the First Basin, we were prevented from learning true accounts of its diminished volume, by finding only its debris covering *in situ* the summit of the central ridge. Shales of various colours are freely intermixed with these limestone strata. In the Third Basin they are said to contain no fossils. Elsewhere some layers are reported to be fossiliferous, while "the thick strata do not contain any fossils."

The Uniontown Coal is a small bed about 200 feet above the Pittsburg Coal, consisting rather of two beds, each 1 foot thick. In the second sub-basin, on the Redstone Creek, it averages 3½ feet. It is not invariably a double bed. It is not yet opened, nor do the rocks above it extend far S. of the National Road; it is perhaps Judge Ewing's 3-feet bed. It is not visible in the Waynesburg Section; and neither the first nor second basins to the Eastward are deep enough to receive it. Henceforth the area of observation, as we ascend in the general series, will continually circumscribe itself, and will finally be confined wholly to Greene County.

The 8-feet stratum of limestone mentioned in the description of the Great Limestone, as occurring at its upper limit, lies between the Uniontown Coal and the coal-bed next above, and adds a new feature to the remarkable continuity over such a wide area of the upper beds of the group of strata as we are considering. In the first sub-basin W. of the Chestnut Ridge it is 8 feet thick; in the second sub-basin, upon the Redstone Creek, it is 10 feet thick; on the Big Sewickly, 8 feet; the same in the Pittsburg Section, and always occupying the same position.

The Waynesburg Coal-Bed.—In the second trough of the Third Basin this measures 5 feet, and lies at an elevation of 300 feet above the Pittsburg Seam. In the Pittsburg and Waynesburg sections it measures 6 feet, and is but 250 feet above the Pittsburg Seam. N. of Mount Pleasant, in Westmoreland County, this bed is the highest in the series, measuring 5 or 6 feet thick; but it has not been found to the S. of that point. Near Uniontown it occurs only 1½ feet thick, and at one locality on the Redstone, 2 feet thick. This seems to be a local degradation of the bed.

There are two exposures of coal-beds which have been ascribed to the Waynesburg Bed, but they do not at all correspond with it in general character. The coal is in thin layers, alternating with thin layers of black slate, the whole measuring 5 feet at Cox's, S. of the Youghiogheny River in the first sub-basin. On the Big Sewickly, at one locality, the same alternations occur, measuring 9 feet in thickness. Several circumstances are calculated to throw doubt upon the identity of these beds with the Waynesburg Coal. At the first-mentioned locality there is evidence of the presence of a bed of good coal, 4 feet in thickness, and open three-quarters of a mile distant, which is more likely to be the Waynesburg Coal-bed.

Above the Waynesburg Coal-bed occur yellow and olive shales and thin sandstone layers, occasionally interstratified.

The highest notable bed left undenuded in the S.W. parts of the Third Basin, lies 55 feet above the Waynesburg Coal, in the Waynesburg Section, and is 2 feet thick; sandstone strata intervene between the beds. Though nowhere opened in the Eastern subdivisions of the Third Basin, its outcrop smut is seen, with that of two others in the neighbourhood of Uniontown, where the first subdivision holds the greatest height of rocks.

This seam is the highest in the series; it is underlaid by sandstone strata, 49 feet thick, beneath which rests a 4-feet seam of coal. These beds are thought to be recognisable in the Savage Mountain coal-field.

A double limestone-bed overlies the last-mentioned coal, composed of two members, each 4 feet thick, and separated by an interval of 4 feet.

A coal-bed 1 foot thick is seen to outcrop 40 feet above the double bed of limestone, and probably is one of three traceable at intervals of 35 feet around the summits of the Uniontown Hills. The uppermost of the three is perhaps a 10-inch coal-bed, next in order in the Waynesburg Section, 30 feet above the 1-foot bed. 20 feet above this are 3½ feet of limestone.

We have now gained an elevation in the series, at which denudation over the whole country, to the N. and E. of Greene County, effectually precludes all further systematic classification. Rocks higher than those last mentioned are found only in Greene County. A section of the rocks of Greene County was attempted, but proved exceedingly meagre in valuable details. It contains 600 feet of higher strata measured, and 200 still higher unmeasured. In the 600 feet we find three coal-beds, not one of which exceeds 1 foot in thickness, and six small limestone beds at various elevations, the highest being 5 feet thick, and 900 feet above the Pittsburg Coal, by estimation.

The last and highest rock observed is a mass of grey and buff micaceous sandstone, 110 feet thick, occupying the highest ground between the head-waters of Ten-mile and Wheeling creeks. Here, if anywhere in the Great Appalachian Coal-field, the geologist should institute a search for Permean fossils identical with the species lately found in Illinois and Kansas, above the productive Coal-measures.

SUBDIVISION III.

DETAILED DESCRIPTION OF THE BITUMINOUS COAL REGION.

CHAPTER I.

THE FIRST BASIN WESTWARD TO PINE CREEK.

THE Eastern extremity of the first bituminous coal-basin crosses the Loyalsock, near the mouth of Plunkett's Creek. The rocks opposite the mouth of Mill Creek, and along the whole extent of that stream, dip gently to the S.S.E. The conglomerate capping the hills may be traced for miles along their summits. At the very head of Mill Creek, the lower beds of the Vespertine sandstone replace it on the hill-tops; and below the mouth of that stream, on the other side of the Loyalsock, the Ponent red sandstone rises 200 feet in the hill, the remaining height consisting of the flaggy brown Vespertine sandstones. In the latter rock occur thin bands of a poor arenaceous limestone, hardly rich enough in lime to be of any value. It assumes a singularly pitted or worm-eaten surface from atmospheric action. It is sometimes 4 feet thick. Upon the top of the hill above referred to, and at an elevation of about 1000 feet above the stream, occurs the conglomerate, apparently about 40 feet thick, dipping S.S.E. The first anticlinal axis, here very abrupt, exposing the red Ponent sandstones on the stream next W. of Lick Creek (another Mill Creek), is traceable in a W. by S. direction, crossing Pheasant Stream, and then Lycoming Creek, half a mile above the mouth of Pheasant Stream. Eastward it ranges in a perfectly straight line, so as to cross Tunkhannock Creek, just above the mouth of its S. Branch. Nowhere does it exhibit dips so great as along the waters of the Loyalsock. The considerable angle at which the rocks dip N. of the Little Loyalsock, causes nearly the whole thickness of Ponent rocks to crop out in one hill, though the perpendicular depth is about 1000 feet. The olive and greenish slates of the underlying strata at the alternation of the Vergent and Ponent series, also appear: they have been usually supposed to contain copper ore. The Vergent rocks come to the surface, near the confluence of Milk Creek and Lick Creek, while they include a thin bed of fossiliferous limestone of good quality for making lime. Near the limestone rises a brine spring, the water of which furnishes a brackish sediment by evaporation. The bottom lands of the Loyalsock are wider than those on most of the other streams in the Northern counties, and contain many good forms. The neighbouring hills are precipitous and rocky, and remarkable for the distinct features of the benches along their sides. Their height varies from a few hundred to a thousand feet; one of them proved to be 988 feet by measurement. On the N. side of this hill, which is 1 mile above the mouth of Elk Creek, the strata, as far as ascertained, are as follows:—For the first 30 feet above the stream, Ponent red shales, then blue sandstone. Above this occur flaggy argillaceous sandstones, somewhat reddish, but more commonly blue and grey. The flat loose pieces of this rock conceal most of the lower beds, resting on the side of the hill, although it slopes at an angle of nearly 70°. A somewhat reddish and heterogeneous calcareous rock, in large blocks, has fallen a short way down to the water's edge: it is an indifferent limestone, probably unfit for use. At the height of 568 feet occurs a bold bench or perpendicular cliff, formed by a bed of coarse white sandstone and conglomerate, about 80 feet thick, embracing a curious variety of white shale 1 foot in thickness. Receding from this escarpment occurs a shelf or terrace of very gentle slope, from which the hill rises by a steep and regular acclivity to the very summit, which is covered with scattered pieces of coarse conglomerate. This hill and the adjoining rivulets were closely examined, and a few excavations were made, without discovering any trace of either iron ore or coal: the latter ought to have presented itself, had the bench described been formed by the Seral conglomerate. A band of red shale near the summit belongs probably to the Vespertine red shales, and may possibly contain some iron ore. The summit of this hill is a broad flat used as a pasture, and the only artificial enclosure required for the cattle is a single bar put across a narrow passage between two rocks. On the S. of the Loyalsock opposite the last hill, a bench exists, apparently on a level with the top of this, while a knob 40 or 50 feet high rises above it, composed of sandstone and conglomerate. Under this last bed is a thin seam of coal 1 foot thick, overlaid by a foot of slaty cannel coal, and resting on a floor of black bituminous shale. The same band of coal was readily discovered in other places, at the base of similar knobs in the neighbourhood. No iron ore was found. The coarse conglomerate occupies only the very highest knobs. The stratification here described belongs to nearly all the hills lying on this creek.

The country around Elk Creek consists of Vespertine rocks. Hogeland's Branch traverses the Red Shales of that series throughout its whole course; it is a rapid stream descending by a series of waterfalls each from 20 to 40 feet in height.

The scenery at some of these waterfalls is picturesque in a high degree. Near the top of the hills around the head of Hogeland's Branch, we find a stratum of poor bluish limestone 1 foot thick, and among the Red Shales, 200 feet lower down, two others, belonging to the Vespertine and Ponent alternations. A mile or two E. of Hogeland's Branch many loose pieces of the conglomerate are scattered about in large boulders, between the head of that stream and the forks of Loyalsock. The rock is valued by the inhabitants for making millstones. A knowledge of the stratum from whence they are derived would prove a guide in seeking for the Coal-measures. On the highest parts of Bennett's Ridge, at the head of Plunkett's Creek, it lies in place, dipping N.N.W. 4°, and under it we find a bed of the Umbral Red Shale.

It was traced for several miles near the heads of Pleasant Stream and Plunkett's Creek. At 2 or 3 miles below the head of Wallace's Run, though the ridge is very high, it does not occur. Bennett's Ridge runs N.E. through Elkland township, S. of Pleasant Stream. The ridge between Pleasant Creek and Rocky Run contains only the lower Vespertine rocks: this is about 10 miles above Ralston. Between 5 and 7 miles E. of Ralston the conglomerate is well exposed, capping the hills, and forming an abrupt or sometimes overhanging wall 25 or 30 feet high, full of dark passages and deep holes. It is not practicable to ascertain the existence of any bed of iron ore which may occur beneath this rock without a considerable amount of digging. Approaching Ralston, the conglomerate gradually descends lower into the hills, which, from the deepening of the valley of the stream, have an elevation of at least 1000 feet above its bed.

Where the Berwick and Towanda turnpike crosses the two branches of the Loyalsock, the land being high from the nearness of the heads of the creeks, the upper formations are comparatively low in the hills. Thus, in approaching from the N., an exposure of Vespertine sandstones is perceived at the foot of Sugar Hill, which dips S. 20° E. The hill is estimated to be 350 or 400 feet in height, and is capped by Umbral Red Shales. A level upon the summit, of a mile in breadth, brings us to Shinersville, where the Seral conglomerate makes its appearance in a little bench, but is much better developed on the S. side of Birch Creek, 5 miles E. of Laporte. At the foot of this bench near Shinersville, bog-ore is seen issuing from under it, at the outcrop of the Vespertine Red Shales. The Seral conglomerate is here from 60 to 80 feet thick. Over it, in the hill upon the S. side of Birch Creek, openings were once made in slate, with a covering of coarse grey sandstone 10 or 15 feet thick. No rock overlies this upon the dead level of a mile hence to the descent of the road into the valley of the main Loyalsock.

These openings revealed the presence of a coal-bed, but not its thickness. Within the Seral conglomerate is a thin bed of coal. Upon the main Loyalsock a N.N.W. dip begins to be seen, and from under the Seral conglomerate issue other ferruginous streams, depositing bog-ore along the outcrop of the Vespertine Red Shales, not more than 50 feet above the water in the Creek. Descending the Creek 7 or 8 miles from the turnpike crossing, a bed of conglomerate is found in the bed of the stream.

Ascending the creek an equal distance, openings occur upon the same coal-bed, from which many tons of coal have been conveyed; but its true thickness we have not ascertained.

The hills between the forks of the Loyalsock seem wholly to consist of Vespertine sandstones, though here and there a small patch of conglomerate is visible upon the summit. There is said to be a coal-bed upon the S. side of Sugar Hill, on the main Loyalsock, 2 miles above the forks, the thickness of which, beneath the conglomerate, is from 8 to 10 inches. This corresponds with the 1 foot of coal figured in the Section.

The meagre sections of the coal series, as developed in this shallow outlying basin of the great coal-field, will be as in column. At the bend of the Loyalsock, 5 miles above the mouth of Plunkett's Creek, is Hillsborough, consisting, at the time the survey was made, of one house, and a clearing in a broad valley. Here, on the S. side of the creek, Vespertine sandstones are exposed, dipping S.E., and resting immediately on the Ponent Red strata at the water's edge. 70 or 80 feet of Ponent rocks are exposed above the water, 2½ miles farther down. Between the E. fork of Plunkett's Creek and the Loyalsock, is a hill composed of Vespertine sandstone, loose pieces of Seral conglomerate lying scattered over its surface. The S. dip on the forks of Plunkett's Creek is from 35° to 40°. The North Branch falls in three-fourths of a mile, full 500 feet from the head of "the falls," downward; the rest of its descent to the Loyalsock is quite gentle. Near the falls, a hill, 300 feet high, is composed entirely of Ponent rocks, the strata of the Vespertine series, having but a few fragments upon its surface. A hill at the mouth of Plunkett's Creek was examined, where we were told coal existed. Ponent rocks were found at the bottom, and Vespertine rocks composed most of the hill; no signs of the conglomerate were found upon its top, though it was so high that the whole valley of the Vergent rocks on the N., as far as Burnett's Ridge, was visible from it, and all the hills around were overtopped by it. On a hill between it and the North Branch of Plunkett's Creek, pieces of the conglomerate were observed scattered about.

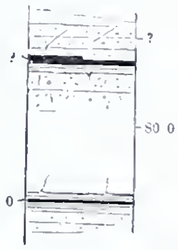


Fig. 333.—Loyalsock.

There are few localities upon the mountains and hills of the Loyalsock where coal is to be found. There is a small bed under the conglomerate, as will be found to obtain elsewhere in the N. basins; there is but one other coal-bed, and that one, over the conglomerate, not great in its thickness, more limited in extent than the conglomerate itself, and found principally between the Loyalsock and Birch Creek. Coal is said to be found at the head of the Mahoopeny Creek far to the E. of this.

We are informed that a bed of coal has been found on the Loyalsock Creek, 5 miles S.S.E. of Dushore, in Sullivan County; the bed is 3 feet thick, but contains only 18 inches of coal.

On the Lee or Dutch settlements there is a coal-bed proved on a tributary of the Loyalsock: it is 3 feet 3 inches thick, and contains only 1 inch of slate. The seam is covered by conglomerate of Nut size. It may possibly be identical with the Towanda Bed.

From the same authority we learn that recent explorations for copper have been made at Jonestown, 6 miles S.W. of Laporte; also half a mile W. of the South Branch of the Towanda Creek, on Albany township, Bradford County. In the latter case the ore is said to consist of several varieties, and is interspersed within a band of shale about 3 feet thick. It has been mined to a small extent.

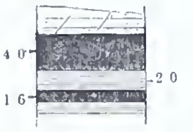


Fig. 334.

Passing to the W. side of the valley of the Lycoming Creek, coal is first opened upon the high summit of the Alleghany, to the left, as we ascend the gorge of Hogeland's Run by the road to the Coganhouse Settlement (see Fig. 334).

Coal, 4 feet; Fire-clay, 2 feet; Coal, $1\frac{1}{2}$ feet; roof sandstone.

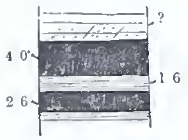


Fig. 335.—Lycoming Creek.

This corresponds very accurately with the measurements of a bed said to have been lately opened at a place 6 miles E. of Hullman's Nail-Factory—which latter is 11 miles above Williamsport, on the Lycoming (see Fig. 335). This is said to read,—

Coal, 4 feet; Fire-clay, $1\frac{1}{2}$ feet; Coal, $2\frac{1}{2}$ feet.

The seam, in both instances, is probably the Tionesta Coal, and corresponds (say the miners) with the sandstone-roof seam of the Tangascootac mines.

Coal was discovered and opened about 18 miles from Williamsport, on the old State Road, between Newbury and Wellsborough. Near the base of the mountain were found loose pieces of slaty sandstone characteristic of the Vespertine series. Above these rocks, which have a perpendicular thickness of about 700 feet, the ridge assumes a more gentle slope, and the soil presents evidence of being derived from the Vespertine Red Shales. This Red Shale is probably not more than 30 or 40 feet in thickness. It is occasionally very ponderous and highly ferruginous, and shows indications of a bed of valuable iron-ore, probably identical with one discovered in other places. Indeed, ore is said to have been found here. Overlying the Red Shale occurs the conglomerate, and loose pieces of other portions of the Seral conglomerate. Its aspect is that of a white silicious sandstone, imbedding small and scattered pebbles of white quartz. It is nowhere visible in place, and is probably about 75 feet thick. Above it occur no rocks in place. The following section exhibits the order of things from the top of the highest bench on the mountain down to the conglomerate:—

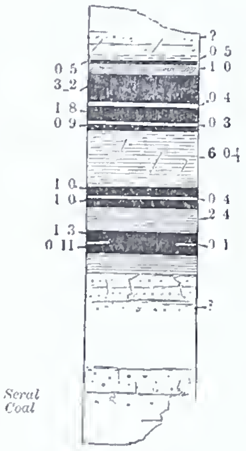


Fig. 336.

Coarse micaceous sandstone containing many vegetable organic remains. Fire-clay, 5 inches; Coal, 5 inches; Clay, 1 foot; Coal, 3 feet 2 inches; Shale, 4 inches; Coal, 20 inches; Clay, 3 inches; Coal, 9 inches. Fire-clay, 6 feet; Fire-clay, with fucoides. Coal, 1 foot; Shale, 4 inches; Coal, 1 foot; Shale, 28 inches; Coal, 15 inches; Shale, 1 inch; Coal, 11 inches. Black Slate, containing *Fucoides*, *Sigillaria*, and *Equisetacea*. Brown sandstone; Seral conglomerate. (See Section, fig. 336.)

This section is compiled from the measurements in several adjacent shafts, in which the quality and thickness are not everywhere strictly the same. The main or upper coal-seam extends for more than a mile along a bench or terrace, which, however, is narrow, the ground sloping rapidly away on both sides down to the conglomerate. Its course is rather irregularly N. for nearly a mile, when it turns E., and gradually falls away towards Hogeland's Run. The S. dip of the Coal-measures soon causes all the coal to disappear as we advance to the N., the Umbral Red Shale coming to the surface and marking the limit of the basin. Beyond these rise the Vespertine sandstones, succeeded by the Ponent Red Shales and sandstones, the latter constituting the principal part of the hill S. of Larry's Creek, and the whole of those lying N. of it, in the tract of country known as the Cogenhouse Settlement. Excavations were made among the Umbral Red Shales N. of the coal, in search of the iron ore which often occurs in this stratum. The shale in some places is exceedingly heavy, containing much oxide of iron; its colour is similar to that of some ores found in the formation, and might readily deceive an observer into the belief of its being a productive iron-ore. Further explorations, however, will probably result in the development of such in this vicinity.

Eastward of Hogeland's Run, on Bope's Mountain, fair indications of the Coal-measures exist, some pieces of the conglomerate being observed on the highest knobs, in a situation indicating the possibility of coal near the summits.

Towards the W., the mountain falls away to a branch of Larry's Creek, called the Roaring Branch, beyond which it rises again to about the same elevation, presenting a flat area of more than a mile square on its summit. The conglomerate rock seems to lie about 40 feet below the highest part of the hill, the outline of which is such as to imply the existence of the Coal-measures. Further W., the hills continue of nearly the same height, but examinations carried on in that quarter, about the sources of the Western Branch of Larry's Creek, did not result in the discovery of any coal. Coal will, no doubt, be found in insulated patches along the summit of the mountain forming the N. limit of the little valley of Tombs' Run. Certainly the coal-bed underneath the conglomerate must exist there, although of too insignificant a thickness to make a return worth its working.

Explorations to some extent were made, several years ago, for coal on some of these hills, but all the shafts were dug in the strata below the Coal-measures, and the highest ground lying in the centre of the trough was entirely neglected.

The Geological Map will show the range of the basin from Hogeland's Run, across the sources of the different tributaries of Larry's Creek, and thence across Pine Creek, near the mouth of the First Fork; and a reference to General Section No. VII. will show the general position of the coal if present, as well as the anticlinal structure of the little valley of Tombs' Run, with its wide and gentle axis, and the synclinal remnant of the Alleghany escarpment, left upon its S. side, and called Short Mountain. This being composed wholly of Ponent and Vespertine sandstones, is of course not elevated enough to have the coal, or even the Seral conglomerate, upon its summit.

In the high tongue of land between the First Fork and Big Pine Creek, the hills have considerable elevation. Near the level of the stream the Ponent sandstones just make their appearance, being immediately succeeded by the Vespertine, which occupy between 800 and 900 feet of the hills. Above this the slopes become more gentle, the soil indicating the presence of the Red Shale. Here a bench in the side of the hill occurs, containing a white sandstone, referable to the Seral conglomerate. The rock is without pebbles, being a remarkably white and pure sandstone, readily disintegrating, and furnishing a sand that would be well adapted for the manufacture of glass. To this succeeds another band of Red Shale, and in a high knoll we find another white sandstone similar to that just mentioned, above which are beds of olive-coloured slates and argillaceous sandstones, holding nearly the position of the lower seam of coal, the existence of which, however, is not indicated. The lands occupying the head of the North Branch of Ramsay's Run, being near the centre of this basin, are the most certain to reward research for coal. Excavations have been made a little above the mouth of the First Fork, in layers of coaly matter, by persons not familiar with the stratification of the region in a position below the rocks. The quantity of dark slate, similar to that of the Coal-measures, is considerable, and it is said that a coal-seam, 8 inches thick, was found. The exploration was, however, abandoned; and this will always be the case when the search for coal is undertaken so far down the series.

CHAPTER II.

SECOND BITUMINOUS COAL-BASIN, WESTWARD TO PINE CREEK.

The second great axis, passing E. from Pine Creek, at the mouth of Slate Creek, keeps a distance of 4 miles N. of Ralston and the head of Lycoming Creek, bending with the latter, E. 20° N.

It crosses the Towanda Creek first 3½ miles S. of Canton Corners, then a second time, by bending a little to the N., 4 miles E. of Canton Corners. It then keeps in the hills, running from 1 to 4 miles from the Creek, crosses the head of the bend in the Susquehanna, where Wysox Creek and the Middle Branch of Wyalusing Creek enter it, 3 miles above its union with the East Branch.

The mountain plateau of the second basin is split nearly from one end to the other by the Schroeder Branch, or Middle Branch of Towanda Creek, usually called by the people of Towanda, Canton Creek, which, having its sources on this broad plateau near those of Stony Run, a tributary of the Lycoming, runs away N. 30° E., dividing the mountain mass into two ridges: the one on the S. is called Burnett's Ridge, the other is enclosed between it and the Towanda Creek.

Standing on the Berwick Turnpike, where it crosses the high ridge between the two Loyalsocks, and looking N., we see the line of Burnett's Ridge, broken only by a few little ravines, where the head-runs of the Loyalsock Creek come down, ranging W. from a point on the turnpike, 7 miles S. of Monroe Corners, passing the head-waters of Elk Creek, Hogeland Tract, and joining the main mountain-land between Plunkett's Creek, which descends from it on the S. and Pleasant Stream, which originates on this ridge and flows thence towards Ralston.

The N. division of this mountain-range begins at the Lycoming, above Ralston. Its N. base runs along the S. side of the Lycoming Creek to its head, then in a straight line to the Towanda Creek, a few miles below Canton Corners, and bending gradually round, to suit the course of the Creek, ends at the mouth of the Schroeder's Branch. This will best be seen by reference to the Map. E. of the South Branch, it continues into Frenchtown Bend, and as far down as opposite Wyalusing Creek. But all the E. portion of this is nothing but low hills of Cadent and Vergent, capped by Ponent and Vespertine strata. Thus we see that the mountain-range of the first basin runs on to the Susquehanna; while the similar ridge in the second basin hardly reaches the river, although this is here flowing much towards the W.

Another circumstance should be noticed. In both these instances the axis on the N. of each ridge seems to lie just at its foot, while that on the S. lies far off—effects occasioned by the unequal slope of the two sides of each axis.

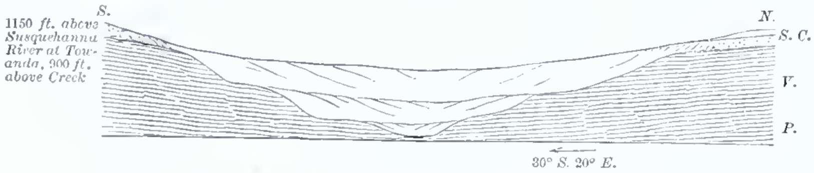

S.
1150 ft. above Susquehanna River at Towanda, 900 ft. above Creek
N.
S. C.
V.
P.
30° S. 20° E.

FIG. 337.—Section of Mountains, on sides of Schroeder's Branch, or Carbon Creek, Second Basin.

Coal.—The E. termination of the coal is upon the mountain between the South Branch and Carbon Creek; the W. does not probably pass W. of the township line of Franklin. Loose blocks of conglomerate are occasionally met with W. of that line, on the top of the mountain.

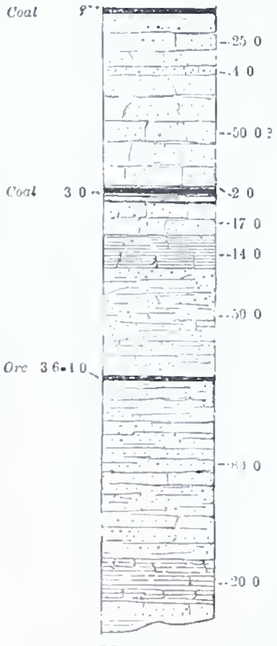


FIG. 338.—Fall Creek. 1 *inch* = 100 *feet*.

The following is a section of the measures at Fall Creek:—

Coal, 0; Sandstone, 25 feet; Pea-conglomerate, 4 feet; Grey and Yellowish Sandstone (some layers coarse and somewhat pebbly, some with coal and charcoal), 50 feet; Slate, with fern impressions, 2 feet; *Coal*, 3 feet; Shale, with Sigillaria, 1 foot; White sandstone, with coaly matter, and impressions, 3 feet; Black slate and coal, 6 inches; White sandstone, somewhat pebbly, with coaly matter, 14 feet; Ferruginous bluish and red shale (position of upper ore-bed), 14 feet; Yellowish-grey fine-grained argillaceous sandstone, 50 feet; Ferruginous shale, and massive mottled grey concretionary iron-ore, 3 feet 6 inches to 4 feet; Yellowish-grey fine-grained argillaceous sandstone, 80 feet; Red shale, 18 to 20 feet; Sandstone, 0.

The upper or main bed has been opened and worked at Mason's Old Mine, 4 miles above the mouth of Carbon Creek, and on the mountain between it and the Towanda Creek, where it was found to measure in coal over 4 feet 7 inches; and also in several places at the old mines 5 miles further W., where it included, according to Mr Johnson's report, from 5 to 7 feet of coal. The following section embraces the strata in the descending order displayed on the stream at Gatiss's Coal Mine:—

Coal, 6 feet; Fire-clay and Sandstone, 20 to 25 feet; White Pea-conglomerate (Seral), 12 feet; Yellowish Sandstone and soft Shale, 50 to 60 feet; Shale and Sandy Marl, 16 feet; Umbral Sandstone ?

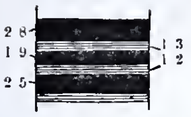


Fig. 339.—Towanda Creek.

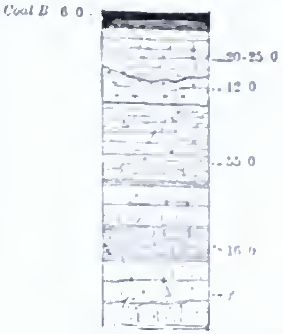


Fig. 343.—Section W. of Gatiss's, Towanda Basin.—1 *inch*=100 *feet*.

Between $2\frac{1}{2}$ and 3 miles W. of the residence of Mr Gatiss, the latter has opened a coal-bed and a deposit of iron ore. The coal is 5 feet 9 inches thick, nearly without slate-partings, and has a sandstone roof and floor of fire-clay. The fire-clay is quite pure, and exceeds 8 feet in thickness. The conglomerate is only 12 or 15 feet below the band of fire-clay. It is about 12 feet thick, and is underlaid by yellowish sandstone and soft shale. Iron ore was found over the upper Red Shale and under the Umbral Sandstone. It was not fully opened, though as much as 12 feet of shale were cut and found full of balls of rough irregular concretionary ore. It is thought (by Mr G.) to be a real stratum.

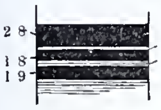


Fig. 340.—Miller's.

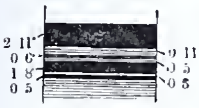


Fig. 341.—Barclay's Drift.

The following are the subdivisions of the coal at Gatiss's :—

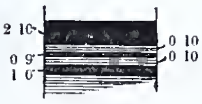


Fig. 342.—Mason's Drift.

Coal, not mined, very bituminous, 8 to 10 inches; Parting, 0; Coal, 2 feet 4 inches; Slate, 9 inches; Coal (Blacksmith band), 6 inches; Slate, 4 to 5 inches; Coal (suitable for grate), 1 foot 8 inches; Slate, 6 inches; Coal, 6 inches; Fire-clay, 0. Two or three species of Sigillaria are found in this coal.

A lower bed, which, as the section shows, has been opened at Fall Creek, measures about 3 feet of coal. This bed is the only one to be found on the mountain between Carbon Creek, Middle Branch, and South Branch. The top of the mountain is capped by the conglomerate, which forms upon it, as well as on all the other high parts of the ridge, a bold white ledge, visible from a distance.

The conglomerate here is quite coarse, often containing pebbles as large as filberts.

The iron ore under the upper bed lies in three bands, the upper of which yields the best ore. This is a close-grained carbonate, very similar to the ore of the Coal-measures in the Western counties.

At the upper limit of the Vespertine sandstone series, we find on Carbon Creek and in other localities a comparatively worthless stratum of red iron-ore. This ore was opened by Mr Johnson on Fall Creek, at a level of about 70 feet lower than the more valuable Umbral ore which underlies the conglomerate. Here it consisted merely of silicious and argillaceous materials, cemented together by oxide of iron, with some ore-balls intermixed. At other places it appears as a very ferruginous red sandstone.

The Falls of Carbon Creek occupy apparently the very top of the Ponent series, although alternate bands of Red sandstone appear still higher up on the mountain-side. Red shales, of a thickness exceeding 10 feet are seen at the falls, covered by hard white and grey sandstone. The same strata doubtless form the falls of the South Branch of Towanda, where we also meet with a stratum of conglomeritic calcareous Red sandstone, 4 feet thick.

About 50 feet below the coarse Vespertine ore the stream dashes over a rocky ledge 30 feet high, and after flowing a short distance, it makes a second leap of 60 feet. Two hundred yards below this the stream passes over a ledge, composed for the upper 60 feet of grey sandstones of the Vespertine period, and for the lower 20 feet of red and green Ponent shales. Here the stream when swollen by rains forms an imposing and beautiful cascade. From the level of the lower ore the creek falls constantly and rapidly for three-quarters of a mile, when it joins Carbon Creek at a point 206 feet above the mouth of the Towanda. The thickness of the Vespertine series at this locality may be estimated at about 600 feet.

Ralston.—The Ralston Coal-field is only an extension of that of Towanda Westward along the Second Basin. Ralston is situated at the mouth of Stony or Rocky Run on Lycoming Creek, 26 miles above Williamsport on the line of the Williamsport and Elmira Railroad. The hills, which are about 1000 feet high, contain at their base the red rocks lying at the bottom of the Vespertine sandstone series, and surmounted by the conglomerate limestone.

The centre of the coal-basin crosses Lycoming Creek, near the mouth of Dutchman's Run, one mile above Stony Run. The anticlinal axis, forming the S. margin of this basin, crosses near the mouth of Pleasant

Stream, while the other axis, bounding it on the N., passes near the mouth of Roaring Creek. The hills, including the Coal-measures, occupy a range of country E. and W. nearly 10 miles in length; but the coal is not continuous over all this extent, being interrupted by deep valleys of denudation. The principal localities of the coal are on a branch of Stony Run, between that stream and Dutchman's Run, on Red Run, the other side of Lycoming Creek, and on Frozen Run, near Astonville. From Ralston, a waggon-road, at a grade of one foot of elevation to every 17, ascends 3 miles to the mines. The height of the coal above the creek at Ralston is about 875 feet, while Ralston itself lies 808 feet above the tide.

The mines of M^{c}Intyre and Robinson are situated on Stony Run, 3 miles from Ralston. The coal-bed worked by them varies from 2½ to 3 feet 2 inches in thickness; the coal is highly columnar, and yields a White-Ash. Iron ore is found in the same position as at Ralston.

On the road leading to the mines, and below the conglomerate, in a bed of dark shale, there is a valuable band of *iron ore*, lying only 4 feet beneath the rock, from which it is separated by a layer of brown shale. It occurs in irregular knotty lumps, closely bedded in a soft reddish and white shale. It forms about one-half of the stratum, and consists of nearly a white crystalline protocarbonate of iron, somewhat resembling a fine-grained sandstone. This is apt to be encrusted with the brown or red oxide. These balls are very solid and heavy, becoming more massive as we penetrate deeper in from the outcrop. In the other half of the bed, which is principally shale, occur scattered balls of the same ore, of a blotched red and white appearance. This ore is admirably suited for the manufacture of foundry iron. This is the valuable Umbral red-shale ore.

The Seral conglomerate in this region varies from 45 to 100 or more feet in thickness: the top of the rock is marked by a terrace, gently receding from the front of the hill to an abrupt slope, formed by a bed of white pebbly sandstone. Between these two sandstone beds we find a seam of rather slaty coal, from 18 to 30 inches thick, underlaid by 30 inches of slate. Over the sandstone occurs another bed of coal, several feet thick, but not of superior quality, the lower part of it consisting of slaty cannel coal, and the rest being rather hard. It includes two bands of slate: one 8 inches, the other, near the bottom, 3 inches thick.

Another coal-seam, between 1 and 2 feet thick, occurs from 5 to 7 feet above the former. It contains 3 inches of slate near the middle, but supplies an excellent coal for cooking, and is much superior to the seam beneath it.

Above this coal we find a bed of shale, containing large nodular balls of *iron ore*, and a little higher another seam of coal one foot in thickness.

A complete section of the strata in the descending order at the *Ralston* Old Mines, on the 3000-acre tract, is appended :—

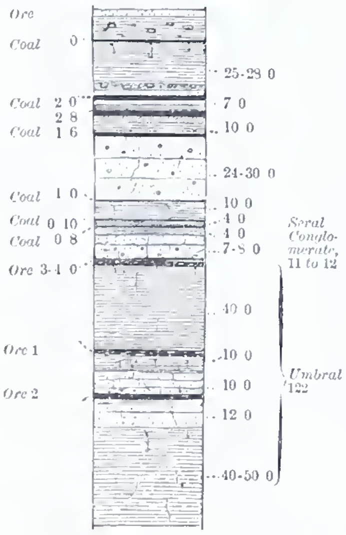


FIG. 344. — Ralston Old Mines. 1 *inch* = 100 *feet.*

Thin bedded shelly sandstone, 4 feet; Shale, with ball-ore, 10 feet; *Coal,* 1 foot; Black slate and shale, 20 feet; *Balls of ore,* 5 inches; Slate, 3 feet; Sandstone, 1 foot 6 inches to 4 feet; *Coal,* 2 feet; Fire-clay, good, 3 feet; Strong slate, 4 feet; *Coal,* 2 feet 8 inches; Fire-clay and sandy shale, 10 feet; *Coal,* 1 foot 6 inches; Conglomeritic sandstone, millstone grit, 24 to 30 feet; *Coal,* 1 foot to 1 foot 3 inches; Clay-slate and shale, 10 feet; *Coal,* 10 inches; Shale, 4 feet; *Coal,* 8 inches; Clay-slate, 3 to 4 feet; Strong brown sandstone, 4 feet; SERAL CONGLOMERATE, 7 to 8 feet; Slaty clay, 6 to 8 inches.

UMBRAL.—*Ore,* some places 3 to 4 feet, here 2 feet; Bluish and greenish clay-shale, 40 feet; *Thin course of balls of good ore in ground,* 1 foot; Clay-shale and black slate, 10 feet; Sandstone, 3 feet; Hard micaceous shelly sandstone, 7 feet; *Red ore-balls,* cold-short, in ground, 2 feet; Green sandstone, 10 to 14 feet; Red shale or marl, 40 to 50 feet.

Crowning the highest part of the hills occurs a bed of conglomerate, 60 feet in thickness, less coarse than the main Seral conglomerate.

The dip of the strata at the mines on Stony Run is gently Westward; on Dutchman's Run on the opposite side it is towards the E.S.E., while a few miles farther up the main branch of Stony Run it is toward the N.W. about 4°.

A somewhat curious feature of this hill are the swamps occurring on its very summit; the largest occupying several acres, entirely destitute of timber, and containing a deposit of *peat* at least 15 feet in depth.

On Red Run the strata are nearly the same as at Ralston. Beneath the conglomerate, the shale containing the iron ore is 34 feet thick, and underneath that is a sandstone 100 feet, succeeded by another bed of red shale. These two red shales correspond with those at Farrandsville, to be hereafter described, excepting that the iron ore occurs at the latter place in the lower bed.

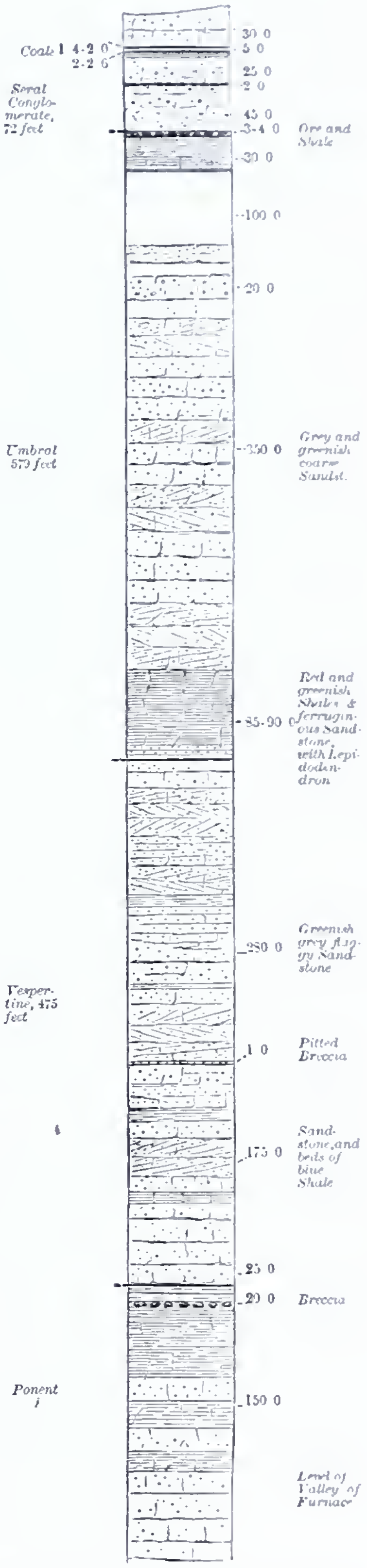

Coal 1 4-2 0
2-2 6
Seral Conglomerate, 72 feet
Umbral 575 feet
Vesper-tine, 475 feet
Ponent
30 0
5 0
25 0
2 0
45 0
3-4 0
30 0
100 0
20 0
350 0
85-90 0
250 0
1 0
175 0
25 0
20 0
150 0
Ore and Shale
Grey and greenish coarse Sandst.
Red and greenish Shales & ferruginous Sandstone, with Lepidodendron
Greenish grey flaggy Sandstone
Pitted Breccia
Sandstone, and beds of blue Shale
Breccia
Level of Valley of Furnace

FIG. 345.—Astonville, on Railroad. Ralston District.—1 *inch* = 200 *feet.*

On Dutchman's Run a remarkable slide in the face of the hill has laid bare the Ponent, Vespertine, and Seral conglomerate series.

The following strata are displayed on the Railroad between Astonville and the mines, near Ralston:—

		Feet.	In.
COAL-MEASURES	Coarse sandstone,	30	0
	Coal, ... 1 ft. 4 in.	—2	0
	Fire-clay,	5	0
	Coal—4 inches of bony in middle,	2—2	6
	Fire-clay and slate,	5	0
	Coarse and pebbly sandstone,	25	0
	Coaly and bituminous slate,	2	0
	Pea-conglomerate and sandstone,	45	0
UMBRAL	Blue and red shale,	2—3	0
	Iron-ore,	1—2	0
	Ball-ore in bluish shale,	2	0
	Blue shale, &c.,	30	0
	Blank,	100 ?	
	White conglomerate,	20	0
	Grey and greenish coarse sandstone, often thickly bedded, and obliquely laminated,	350	0
	Red and greenish shales and ferruginous sandstone, with Lepidodendron,	85—90	0
VESPERTINE	Greenish flaggy sandstone, with beds of grey sandstone and blue slate, obliquely laminated, with 1-foot bed of rotten calcareous brachia, 350 feet visible—in all	475	0
PONENT	Red sandstone and shale,	25	0
	Green sandstone, with brachia,	20	0
	Red shale and sandstone,	150	0
	Level of valley of furnace,	...	

The coal of the Astonville Mines is opened in several drifts. It is in two benches—the lower about 2 or 2½ feet; the upper, from 16 inches to 2 feet. The fire-clay between is 5 feet thick. In the lower coal about midway is a bony layer of 4 inches. Two drifts have been opened at an interval of about 300 yards. The coal is shot down steep slopes or inclined planes.

The ore is drifted on just under the conglomerate, which is pebbly in its lower layers, but a coarse, heavy-bedded Pea-conglomerate, for nearly 50 feet above this. The matrix of the ore is a fine bluish and red mottled argillaceous shale. The ore lies from 4 to 6 feet below the rock. It is a brown and grey carbonate in a bed, not concretionary, from 1 to 2 feet thick, but is now faulty and thin. Below the stratified ore, and nearly in contact with it, is a nodular ore of a concretionary form, and more ponderous. It also is a grey and brown carbonate. These nodules are irregularly placed at intervals in the shale. Below the level of the Ore-drift the rocks are concealed for about 30 feet; but, from the aspect of the surface, I make no doubt this interval is occupied by shales. At 30 feet, a drift, mined for ore unsuccessfully, has brought to light bluish-grey argillaceous shales, with some impressions of *Lepidodendron*. These shales are evidently somewhat calcareous.

Just S. of the locality of the mines there is a deep ravine, in which a brook descends, and which, on account of the amount of the fallen conglomerate, shows no exposures except just below the Bridge, where there is a mass of flaggy Umbral-like sandstone, included in the section. On the opposite or S. side of the ravine on the Railroad, the first rocks to be seen are immense blocks of a very white Pea-conglomerate, which has the appearance of dipping N., but may be the Seral which has slipped down.

A short distance S. of this, the rock is undoubtedly in place, and is here a coarse, thick-bedded, light-grey sandstone. The mass of this is not less than from 75 to 100 feet, and is succeeded, further S., by a more greenish and flaggy rock, but still generally coarse. Lithologically, these rocks present more clearly the characteristics of the Vespertine Strata than any other, and as such we have chosen to regard them.

Directly behind the Ralston House at the foot of the hill, a crumbly red-shale is seen underlying the heavy cliff of flaggy grey and greenish sandstone. Just at the top of this is a peculiar bluish-grey breccia, apparently calcareous, associated with an impure iron-ore. This rock weathers very ragged and pitted, and is doubtless the same as that marked in the section as in the shales at the top of the Ponent.

As the rocks of the Ralston Hill dip N., while those on the Railroad, for some miles N. of Ralston, dip S., Ralston must be on the S. side of the synclinal, which includes the coal in the higher levels.

Frozen Run enters Lycoming Creek on the W. side below Stony Run.

There are two furnaces at Astonville, a small one using charcoal, which has been in operation successfully, and a complete furnace, 14 feet across the boshes, adapted to hot-blast. This was chilled in the first blast, and is not now (1854) in operation. It was to use anthracite mixed with the coal of the hill. The ore, when roasted, looks grey and vitreous. Three tons of ore are required to yield one ton of metal at the charcoal furnace.

The strata in the hill at *Cartersville*, on the Lycoming Creek, 1½ miles above Ralston, are as follows:—

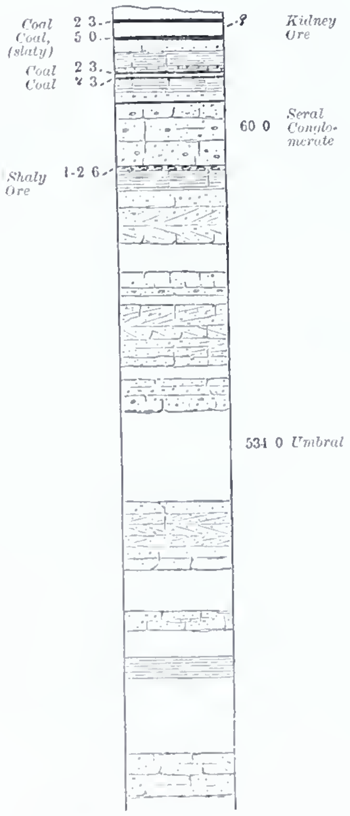


FIG. 346.—Section of Hill at Cartersville, 1½ miles above Ralston.—1 *inch* = 200 *feet*.

		Feet.	In.
	Coal,	2	3
	Blank, said to contain kidney ore,	...	
	Coal—slaty, and not mined,	5	0
	Slate and sandstone,	25—30	0
	Coal—in one bench good,	2—3	0
	Slate,	8—13	0
	Coal—good, and harder than the above,	2—3	0
	Slates, passing into slaty sandstone,	20	0
SERAL.	Sandstone, becoming pebbly,	15	0
	Pea-conglomerate, thick-bedded,	45	0
UMBRAL.	Bluish and red shale,	1—2	0
	Shaly ore,	1—2	6
	Red and blue mottled shales, about	20	0
	Coarse greenish-grey, somewhat pebbly micaceous sandstone, obliquely bedded, and containing vegetable impressions,	50	0
	Blank,	25	0
	Coarse white sandstone, lower beds pebbly,	25	0
	Blank,	10	0
	Coarse sandstone—thin-bedded impressions,	65	0
	Bluish flaggy sandstone,	15	0
	Conglomeritic sandstone,	15	0
	Blank,	85	0
	Bluish and olive micaceous flaggy sandstone (seen at quarry)—some beds argillaceous, abounding in vegetable impressions,	60	0
	Blank, containing a few beds of micaceous sandstone,	80	0
	This brings us to the base of the cliff; below this red shale, and a mass of shaly gravel intervenes to base of Umbral—about	90	0

There can be little doubt that the two lower seams at Cartersville are identical with those worked together in the drifts of the Ralston Hill—the interval in the latter place having diminished. On the highest part of the Ralston Hill, the upper or five-feet seam of Cartersville is said to have been found. At Cartersville there is a seven-inch coal over the highest noted in our section. At the latter locality, ore like that at Ralston is found, about 80 feet beneath the lowest coal. It lies in red and purple olive mottled shales, and in general is more argillaceous than at the Astonville opening, though some masses are solid, containing white and brownish carbonate of iron. Its thickness varies from 1 foot to 2 feet 6 inches. There are two openings upon the bed, entering W. by N. The more S. of these has been driven but a few yards. The ore proved more shaly and impure than that of the other opening; the nodules are often crumbly shale, bluish and mottled purple, charged throughout with carbonate of iron. The average thickness of the bed in the two drifts is about 18 inches.

The furnace at Cartersville is a very solid structure of the Umbral Sandstone of the quarry; it measures 12 feet in the boshes.

The Vespertine Rocks between Ralston and Cartersville dip very gently W. by N.

On the railroad between Ralston and Canton there are, by estimation, from 550 to 600 feet of Ponent sandstones and shales visible; passing these, olive and reddish shales and flags may be seen to the thickness of 120 feet, full of Fucoids, then 50 feet of heavy-bedded greenish sandstone, followed by reddish sandstone 50 feet thick, after which the road passes through 75 feet of red shales and greenish sandstones, and then olive and red sandy slate.

Near Alba, olive shales of the Vergent are seen dipping N. Between Alba and Troy, and at the latter place, are North-dipping red shales and sandstones of the Ponent and Vespertine series.

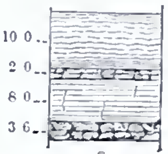


FIG. 347.—Sellard's Ore, on Schroeder's Branch of Towanda Creek, 2 miles S. of Canton.—1 *inch*=40 *feet.*

Returning S., and crossing Laurel Hill by the road up Trout Run, a N. dip is observed on the S. side of the stream, and a S. dip on the N. side, indicating this as the position of the synclinal axis of the Coal-basin. Ascending the hill, we have indications of the presence of Ponent rocks, for an elevation of from 300 to 400 feet. This is succeeded by Vespertine strata, on the upper side of which we find two bands of the Umbral red shale. *Iron ore*, in loose pieces, was found near the upper of these beds of red shale, and not far from the summit of the hill, which is surmounted by coarse white sandstone and Seral conglomerate. Above this last rock, one of the lower beds of coal may possibly exist, where the knobs rise to a sufficient height from this level. There can be little doubt that the red shale below the conglomerate includes a band of iron ore similar to that found at Ralston.

The country S. of Laurel Hill is extremely rough, being covered by the Umbral and Seral series; but that N. of the hill is more gently undulating, Ponent strata alone capping the hills, and producing a soil fit for farming. The N. anticlinal axis of the Ralston Basin crosses the road a little S. of the county line, while the S. axis passes near the head of Trout Run.

The next place in our progress W., where this basin contains coal, is on the First Fork of Pine Creek. Heavy masses of conglomerate strew the flats along the First Fork, about 3 miles from the mouth of Bear Run, which heads near Larry's Creek. We no longer find the Ponent Rocks above the streams, but they rise to their level near the Block-House Fork, and a little below the old English mills. The hills are between 700 and 800 feet high, containing about 100 feet of the conglomerate, supporting 100 feet more of higher strata. On a stream known as Three-mile or Porcupine Run, opposite Wolf Run, the conglomerate, and above it the brown sandstone, are well exposed. Between them no bed of coal was discovered; but above the sandstone a coal-seam was found consisting of two bands, each about 1 foot thick, separated by a layer of hard shale. The lower band in this seam is a beautiful black shining coal. Below it lies a bed of hard blue shale. Much search was made for iron ore, but without success. Whether other beds of coal exist in this neighbourhood is uncertain, but the country seems well deserving of further investigation. The conglomerate caps the hills on both sides of the fork, a little distance N. and S. from the spot where the coal was found. On the E. side of the fork, and on the Block-House Branch, the indications of coal are less promising than on the W. side. An unsuccessful search was made for the iron ore of the Umbral Red Shale. A ferruginous band in the red shale, about 150 feet beneath the conglomerate, implies that ore might be found here if an adequately minute exploration were made, assisted by proper diggings. Specimens, seemingly of good quality, were found sticking in the upturned roots of trees between Porcupine Run and the old English mills.

About the time these discoveries on the First Fork of Pine Creek were made, a person seeking for limestone on a wild tract a few miles to the W., stumbled upon a bed of coal; a continuation, perhaps, of the seam above described. In tracing the basin in that direction, other beds were discovered and opened, to which I shall now refer. The localities are at the sources of Otter, Day's, and English's Runs, which empty into the First Fork, and of Trout Run, which empties into Big Pine Creek, below the Second Fork. The surface is gently rolling, but very elevated; the obscurity of the exposures, and a considerable amount of dip in the strata, cause the tracing of the coal in this neighbourhood to be rather difficult, as a section made across the basin here would show.

On the very highest lands to the N. and N.W., the seral conglomerate either caps the summits or leaves very little room for the "brown rock" which overlies it. A dip to the S. carries down these rocks, and soon brings in the coal at a level considerably below the tops of the hills; but the ground continuing to slope also to the S. and E., it becomes difficult to determine how far the coal extends in those directions. About 3 miles N. on the road towards Babb's, the hill suddenly falls off about 200 feet, exposing the lower band of the Umbral, and the upper part of the Vespertine Rocks, brought to this elevation by the S. dip. Still farther North, the level of the country is much lower. Where the road crosses Otter Run, the "brown rock" above the conglomerate just rises to the surface, forming the lower part of the bank; above this is the lowest coal-seam, which is 2 feet 6 inches thick, containing a thin band of fire-clay, and underlaid by another bed of fire-clay 2 feet thick. The outcrop of another coal-seam shows itself a little higher up in the same digging. The fire-clay mentioned is of good quality, suitable for the manufacture of fire-bricks. Another coal-bed was found, 25 feet above the last, in a neighbouring bench in the hill. It was opened too near the surface for us to ascertain its quality; its thickness is 3 feet 8 inches, including 2 inches of slate. Below it lies a bed of fire-clay, similar to that of the Middle Coal-seam. The extent of this upper bed cannot be great, but the other beds probably underlie 50 or more acres of surface.

Tracing the conglomerate towards the N., it appears near the top as a coarse pebbly rock, and lower down as a reddish brown sandstone. The thickness of the whole stratum is about 150 feet. On the N. slope of the hill towards the old English settlement, the Umbral shales appear. About 200 feet lower down the soil indicates the lower red-shale bed, and here possibly the iron ore may exist. The hills N.W. of the coal-openings rise more suddenly, and contain the conglomerate. How much farther the Coal-measures extend towards the S. and E. can only be ascertained by systematic diggings and accurate measurement beyond the resources of the survey. At some places in those directions the elevation seems to be as great as at the coal, but a change of dip must occur before we proceed far in that course. The brown sandstone is exposed below the coal on Otter Run.

Coal may hereafter be found at other points on these high lands between the First Fork and Big Pine Creek, but it cannot occupy much extent of surface. It may be worth the attention of the owners of lands lying at the head of the S.W. Branch of Otter Run, or about 5 miles from Callahan's, to excavate for coal, as the appearances there are indicative of the Coal-measures, and the conglomerate does not reach to the highest summits of the country. Examinations were made there, both for the coal and the iron ore of the Umbral series. A pit dug in the red shale about 12 feet, did not, however, bring either substance to light; but it is probable that, if the ore exists at all in this neighbourhood, it is chiefly in the lower bed of red shale, for we subsequently found it there on the W. side of Pine Creek, nearly opposite Callahan's. At this spot it is not, however, well exposed, being only about 6 inches thick, and composed of hollow elliptical nodules, containing sometimes an undecomposed blue centre.

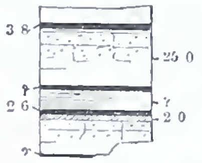


FIG. 348.—Otter's Run.

Tome's Creek enters Pine Creek on its W. side, heading near the corner of Lycoming County. The anticlinal axis N. of the Coal-basin we have been describing crosses the main creek just above their junction. Ascending the mountain by a road crossing over to the Coudersport Road, the Ponent rocks show themselves for the first two-thirds of the way up. Near the top of the formation we meet with two beds of the *blue calcareous* *conglomerate,* and another about 100 feet higher up, among the lower beds of the Vespertine series, which continues for 100 feet more. Above this we find a bed of iron ore in the Umbral shales, at one time dug in several places: it varies in thickness from 2 to 3 feet. From the iron ore to the top of the hill—a vertical space of 40 feet—the rock is the white Seral conglomeritic sandstone, presenting at the summit may pebbles.

CHAPTER III.

THE THIRD COAL-BASIN WESTWARD TO PINE CREEK.

The next Coal-basin towards the N., or the third in order, is that of Blossburg, on the Tioga River.

The hills on the S. side of the river, for a few miles above Blossburg, are capped by the conglomerate; the Umbral red-shale rocks come out on their S. slopes, the dip to the N. being considerable. No coal has been found on that side of the river, excepting near Blossburg, though it may possibly exist S. of the valley, near its source. The coal-formation extends E. nearly to the head-waters of Tioga River, but has not the thickness which it attains farther W.

On a stream called Little Falls Run, 9 miles above Blossburg, openings were made some years ago, under the direction of one of the mining companies of Blossburg, which developed a seam of coal about 3 feet thick, and some small bands of iron ore. A bed of conglomerate, 20 feet thick, occurs here between the layers of slaty sandstone, dividing this last rock into two portions: the lower is of considerable thickness; the upper one sustains the seam of coal.

Above the coal rests a bed of black shale nearly 20 feet thick, containing *kidney-formed iron-ore* of excellent quality, though not abundant, above which are three layers of a poorer species of iron ore in flat slabs, measuring 4 inches in thickness. Over the shale with ore lies a bed of slaty sandstone, extending to the summit of the hill.

The dip of the beds at this place is towards the N. At the E. side of this hill the sandstone which forms the summit contains some small pebbles, and somewhat resembles a conglomerate: it includes, also, some small bands of coal.

The next stream towards the W., which furnishes a good view of the strata, is Fellow's Run; but no coal has been opened upon it. About three miles above its mouth this stream forms, by three bold leaps, a cataract of 60 feet in depth. Below the lowest of these, the conglomerate and sandstone rock rises in perpendicular walls to the height of the top of the waterfall, or to a level of 430 feet above the bridge at Blossburg; while the elevation of the same on Morris's Run, lying farther W., is about 300 feet.

The following section of the strata at Morris's Run was furnished by Mr Young:—

	Feet.	In.
Coal, all good,	4	0
Sandstone, somewhat pebbly,	8—10	0
Shales, with balls of iron ore,	4—5	0
White and grey sandstone,	6—8	0
Bituminous slate,	1	3
Coal,	1	5
Bituminous slate,	2	6
Coal,	0	2
Slate and sandstone,	16	0
Coal, resting on fire-clay,	1	4
Slate,	3	0
Slate, with balls of ore,	4	0
Strong slate,	10	0
Coal, in two benches,	5 ft. 6 in. to 6	0
Slate and fire-clay, with 8 inches coal in middle,	16	0

	Feet.	In.
Coal,	3—5	0
Pebbly sandstone,	40	0
Shale,	1	0
Coal,	16 in. to 1	6
Slate,	1	0
Coal,	0	15
Slate,	15—20	0
Conglomerate,	6	0
Iron shale, with very little ore,	3	0
Coal,	0	10
Clay-slate,	6	0
Green sandstone,	15	0
Red shale or marl,	30—35	0
Sandstone, with 3 feet of sandy limestone.		

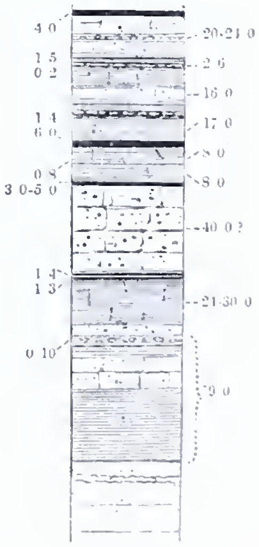


FIG. 349.—Morris's Run Strata, near Blossburg. 1 *inch* = 100 *feet.*

The highest Coal-measures in the Blossburg Basin lie between Morris and Coal Runs, and are 165 feet above the Blossburg Main Coal ; but at Blossburg the highest stratum is about 120 feet above that bed. The capping rock here, at Morris's Run, is a pebbly sandstone.

It will be observed that there is some want of harmony between the preceding Section and the following, representing the stratification at *Blossburg*, for which we are indebted to Messrs Humphreys and John Evans. The main beds of coal are, however, the same ;—

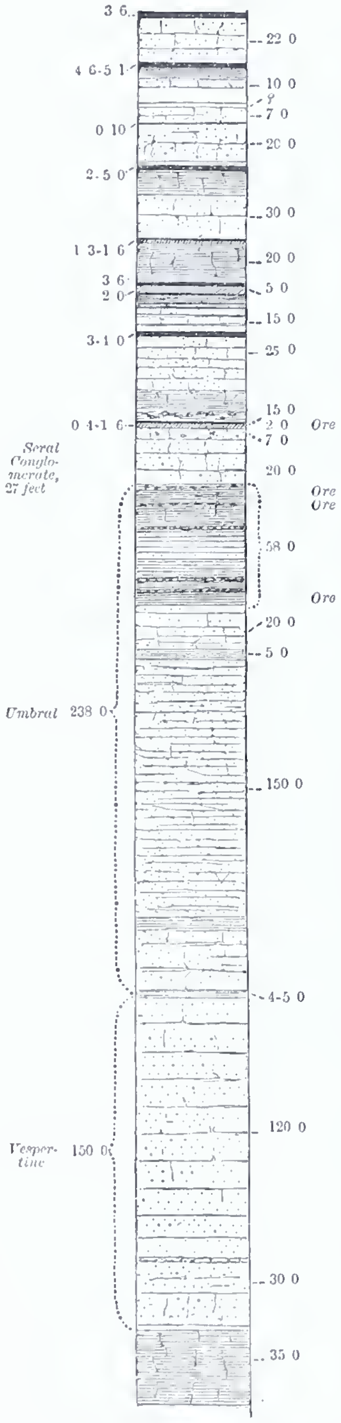


FIG. 350.—Blossburg Strata. 1 *inch* = 200 *feet*.

	Feet.	In.
Coal, all good,	3	6
Space,	22	0
Coal, 3 feet 6 inches, good,	4½—5	0
Slate and Sandstone,	10	0
—— blank.		
Pebbly sandstone,	7	0
Coal,	0	10
Sandstone,	20	0
Coal, dirty,	2—5	0
Slate and sandstone,	30	0
Coal, 1 foot 3 in. to	1	6
Fire-clay,	3	0
Slate,	20	0
Coal, 3 feet, good, the Morris Bed,	3	6
Fire-clay,	4—6	0
Coal,	2	0
Argillaceous sandstone and slate, with two thin coals,	12—15	0
Coal, thickest at Bear Creek,	3—4	0
Micaceous sandstone, thin-bedded,	25	0
Shale, with 1 foot kidney ore,	15	0
Coal, kidney bed, 4 in. to	1	6
Impure fire-clay,	2	0
Pea-conglomerate,	7	0
White sandstone, in part suitable for making glass,	20	0
Shales, with lean oolitic ore,	1	6
Ore,	1½—2	0
Red and mottled shale,	6	0
Ore,	0	6
Shale,	10	0
Shale, with coarse nodular ore,	2	0
Argillaceous sandstone and slate,	20	0
Shale, with 18 inches of grey ore,	4	0
Slate, with 7 inches of ore,	6	0
Slate,	6	0
Dark brown micaceous sandstone,	20	0
Red shale and green slate,	5	0
Greenish grey sandstone to level of railroad,	150	0
Red shale, about	4—5	0
Vespertine sandstone, calcareous bed 30 feet from bottom,	150	0
Red shale and marl,	30—35	0
Green flaggy sandstone.		

As some anticipations exist that the coal will be developed in Elk Mountain, the S. margin of the basin, it may be desirable to present in this place a general description of its summit.

Near the top of a high ridge between the forks of Carpenter's Run, a tributary of the Tioga from the S., occurs a stratum of fine-grained white sandstone, which readily disintegrates into good glass-maker's sand. Below this we meet many loose pieces of conglomerate, which occurs in place 100 feet higher up, constituting benches within 50 feet of the summit, and about 500 feet above the Tioga River. This rock is about 50 feet in thickness, being in some places a coarse conglomerate, in others passing into sandstone ; it caps the whole ridge opposite the mouth of Fellow's Run, for a mile or more back from the river. Its dip is towards the N.N.W. The same rock has been encountered farther E. on the same side of the Tioga, forming the summit of the hills. It is in vain, therefore, to look for workable coal in these positions ; the most that can be hoped for being a small imperfect seam, about 10 inches thick, which is occasionally found beneath the stratum.

The rocks in the bottom lands along the river above Blossburg belong to the Vespertine series, and contain some layers suitable for whetstones. The Ponent rocks do not show themselves.

Coal Run, upon which some of the mines above Blossburg are situated, enters the Tioga from the N.E. Its source is not quite a mile from the river. The hills around it are 400 feet above Blossburg. A nearly continuous section of the strata was obtained on this run. The highest bed measured is at an elevation of about 284 feet above the river, above which occurs a considerable thickness of rocks without exposures. The section (see Fig. 351) is as follows:—

Brown sandstone, with kidney ore shut out by the sandstone; shelly, thin. *Coal*, chiefly cannel, 3 feet; fire-clay, 2½ feet; shale, 15 feet. *Coal* (the fire-clay coal), 18 inches; fire-clay, 2½ feet; shale, 2 feet; nodular ore band, 4 inches; shale, 3 feet. *Coal*, 3½ feet (the Morris Coal); fire-clay, 2½ feet slate, 10 feet. Sandstone, vegetable remains, 30 feet; fire-clay, 6 inches. *Coal*, cannel (including two seams of slate 12 and 3 inches thick), 3 feet 10 inches. Shale, with rich kidney ore (aggregate thickness, 6 inches in 3 feet of shale), 32 feet. *Coal*, too far below the ore to be worked with it, 1 foot; this is the kidney coal. Sandstone, 30 feet. *Coal*, cannel, 2 feet; Olive shales, thickness unknown. Sandstone, with vegetable remains, passing downwards into conglomerate. Then the Vespertine red shales are seen alternating with sandstone strata.

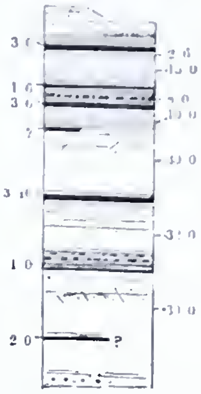


FIG. 351.—Coal Run.

The difficulty of identifying the beds already noticed with any in the column here given, in the absence of all traces of calcareous strata, will be at once apparent.

The beds of the next section (Fig. 352) are not open to the same indefiniteness as to stratigraphical position; they evidently coincide with those in the Towanda, Otter Run, and Morris Run.

Coal is obtained on Bear Creek, North of Coal Run, on the same side of the river. A thick bed of sandstone, part of which is pebbly and about 50 feet thick, forms the upper part of the hill, under which we have, after a few feet of intervening unknown rocks,

Coal, variable, sometimes 1-foot shale, embracing 4 inches of iron ore, 10 to 12 feet. *Coal*, 3 feet 7 inches; fire-clay, 2 to 3 feet; *Coal*, lower half cannel, 14 inches; dark sandstone, 12 feet. *Coal*, 1½ feet. Interval. Sandstone, imbedding pebbles, 30 feet. Shale, 3 to 4 feet, containing iron ore. Sandstone, conglomerate; Umbral shales.

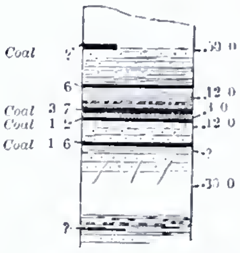


FIG. 352.—Bear Creek.

The upper coal occurs on the South side of the creek, where it is 1 foot 6 inches thick; but on the North side it is entirely wanting. The ore in the next stratum is good, but small in quantity; this bed is also visible on Coal Run. The next bed is the main coal-seam of Blossburg; it has been opened in five different drifts, two on the South side and three on the North side of the creek, at an elevation of about 280 feet above the railroad, not quite a mile distant. The quality of this coal is somewhat injured by the amount of sulphuret of iron occasionally present, from which, however, the chief part of the bed is comparatively free, having a fine brilliant lustre. A fault, crossing the three drifts on the North side of the creek in a N.E. and S.W. course, throws down the coal 3 feet. Large quantities of this coal are carried down the Tioga valley in the winter. The fire-clay under this coal contains *Stigmaria ficoides*. At its outcrop occurs a large deposit of exceedingly tough clay derived from this bed, well adapted for the manufacture of fire-bricks.

The 18-inch seam of coal has been partially mined. The sandstone which underlies it is rather remarkable, passing in its lower bed into a coarse conglomerate.

Under the latter lies another sandstone, and beneath that the Umbral red shale.

Beneath the Seral conglomerate a band of iron ore was struck, which upon being pursued into the hill thinned entirely away. Its appearance justifies further exploration.

The shale containing this ore is nearly 5 feet thick; at its outcrop the ore consists largely of long elliptical balls of a very argillaceous brown ore, lying closely adjacent to each other, and forming more than one-half of the stratum. Each elongated nodule exhibits externally a series of concentric crusts, which readily peel off by exposure to the atmosphere. Beneath the balls lies a nearly solid layer of a heavy yellowish-grey ore, about 6 inches thick, having a true oolitic structure. These beds appear to be shut out by the overhanging sandstone at a short distance from the surface. Other excavations have been made for ore in the other red bands lower down in the series, but unsuccessfully. The conglomerate and sandstone of the two beds described, strew the hill-sides in great quantity, and furnish an excellent building-material.

Half a mile N. of Bear Creek, and parallel with it, is the denuded valley of East Creek, on the N. side of which the hill is capped by a thick bed of sandstone passing towards its lower part into a conglomerate. Underneath this lies a stratum of brown shale, 15 feet thick, containing four bands of nodular ore, included in a thickness of 7 feet of shale, the aggregate thickness of the ore being 13 inches. This bed of ore is the most promising hitherto met with in the region. The chemical composition of the ore we may hereafter furnish.

Below the shale is a thin layer of sandstone; then a black shale, including a thin seam of cannel coal; and 15 feet under this, another seam of ore 15 inches thick, it is said, occurs; and beneath it again a bed of coal 21 inches in thickness.

A considerable S. dip occurring between East Creek Hill and Bear Creek Hill, the sandstone capping the summit of the former, is probably the same as that which underlies the coal-openings along the latter. On Limestone Hill, half a mile further N., the highest rocks are the thin-bedded Vespertine sandstones extending from within 200 feet of the base to the summit. At its base the limestone so often found at the alternation of the Ponent and Vespertine series, shows itself with a thickness of at least 8 feet, consisting of heterogeneous materials, closely cemented by calcareous matter. It has a variegated aspect, like certain *breccias.* It is a durable rock, well adapted for building-stone, but is too impure to be converted into lime. It is underlaid by a bluish micaceous sandstone, furnishing an excellent building-stone. The dip here is at an angle of 5° towards the S.S.E.

North of Limestone Hill, some of the lower layers of the Ponent series appear above the bed of the valley. In one particular band of red micaceous sandstone occur numerous mutilated remains of a highly curious fossil fish, the *Holoptychius.* Further N., still lower rocks appear.

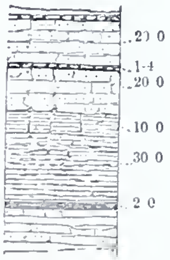


FIG. 353.—Blossburg Vespertine and Ponent.—1 *inch* = 100 *feet.*

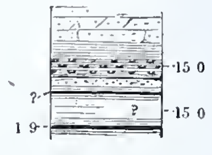


FIG. 354.—East Creek.

The following section exhibits the alternation of Vespertine and Ponent strata, displayed at Blossburg :—

Brown concretionary calcareous Conglomerate, 0; Greenish-grey flaggy Sandstone, 20 feet; Brecciated or lower calcareous Conglomerate, 1 to 4 feet; Greenish and bluish-grey micaceous Sandstone, 20 feet; Red Marl, streaked with blue blotches, 10 feet; Red marly Shale, 30 feet; Grey micaceous sandy Slate, 2 feet; Greenish-grey micaceous Sandstone, 0.

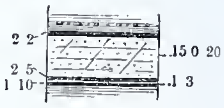


FIG. 355.—Johnson's Creek.

The plane of contact of the Vespertine and Ponent strata rises N. 350 feet to the mile.

On the W. side of the Tioga River, between the heads of Johnson's Creek and Boon's Creek, 3 miles from Blossburg, the Coal-measures occupy the hills, though little is known of them at this locality. The following account of the stratification on Johnson's Creek was furnished by the superintendent of the mines at Blossburg.

Near the summit occurs a shale containing nodular iron-ore; below this, a bed of coal 2 feet 2 inches thick; then 15 or 20 feet of sandstone; then another coal-seam embracing 2 feet 5 inches of coal, 15 inches slate, and 22 inches coal,—in all, a bed about 6 feet in thickness.—(See Fig. 355.)

On West Hill, near the mouth of Johnson's Creek, there is a sandstone passing into fine-grained conglomerate about 50 feet in thickness, underlaid by 4 feet of olive-coloured shale, containing about 2 feet in the aggregate of *iron ore* near its outcrop. The lower portion of this ore is of a greenish-grey colour; the upper is reddish, and sometimes oolitic in its structure. At the outcrop the greenish-grey kind is 1 foot 4 inches thick, the red ore 9 inches. The whole bed shows signs of diminishing in thickness when followed in towards the hill, but possibly it may again augment. At the foot of the hill a considerable deposit of *bog ore* has been collected, apparently from this stratum.

Crossing this coal-basin at a point further W., in a S.E. direction from the S.W. corner of Charleston Township, the following features present themselves: The hills in this part of the township are capped by the Seral conglomerate, the material used in the construction of the Court-house at Wellsborough. Passing S.E., crossing the forks of the First Fork or Babb's Creek, the conglomerate is seen to occupy the tops of all the high ridges, being nowhere met with below the summits. The upturned roots of the trees furnish no indications of coal smut. S. to the head-waters of the First Fork, near the Blossburg Road, the conglomerate caps the summits. In so wild a country it is impossible always to pronounce with positiveness upon the non-existence of coal in a part of a basin like this, where a slight dip may bring in, unperceived, the lower part of the Coal-measures. This neighbourhood was carefully examined, and if the coal does prevail, it cannot cover much extent. Further W. the Coal-measures have been discovered across Wilson's or Yarnall's Creek entering the First Fork at Babb's, and heading towards Wellsborough, and the coal opened on the W. side of the stream. On the E. or opposite side, coal smut was also found by us at the mouth of Wilson's Creek. The dip is gently N.; and about 5 miles above or towards the N. it is S., forming the basin, in the centre of which lie these insulated patches of Coal-measures. The tops of the hills at the two boundaries mentioned consist of the conglomerate, or the brown rock above it, on the very highest knobs, gradually descending to a rather lower level in the basin, they have over them for a considerable extent of surface a moderate thickness of strata, which may be found to contain one seam of coal.

Between 100 and 200 feet below the conglomerate there occur abundant signs of a bed of iron ore, visible along the brow of the hills on each side of Wilson's Creek. Some amount of excavation, however, would be requisite to develop it. Along Wilson's Creek the Vespertine series is not very thick—the hills containing the Coal-measures being apparently not more than 600 feet high, while the Ponent red shales just appear above the bed of the valley.

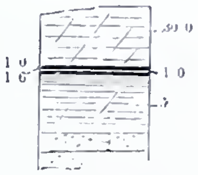


Fig. 356.—Wilson's Creek.

The coal occurs between 2 and 3 miles above Babb's, at the mouth of Wilson's Creek. It overlies a bed of sandstone reposing above the conglomerate. The floor of the coal is a dark brown shale. The seam is double, the upper portion being 1 foot in thickness, the lower, 18 inches, both of good quality. They are separated by a band of dark shale 1 foot in thickness; the roof of the coal-bed consists of black shale full of vegetable fossils. The hill rises only about 30 feet higher than the level of the coal, and presented no indications of another seam, or of a band of iron ore, though much search was made.

Half a mile N. from the opening made in the coal, the conglomerate rock is finely exposed, exhibiting itself in a bed about 35 feet thick. Receding a little from the front of the hill, a bench rises about thirty feet from the conglomerate. On the top of this flat the upturned roots of the fallen trees disclose numerous fragments of iron ore. The indications of ore are tolerably abundant from this point across to the Stony Fork, and the smut of the coal is also traceable throughout the same tract; but whether more than one coal-bed occurs, cannot be ascertained without much excavation. The conglomerate lies high, but some points of the surface tower a little above it. The outline of these high lands is undulating, the growth is open, and would furnish much timber adapted for making charcoal. On both sides of the Stony Fork the conglomerate crowns most of the hills until we advance several miles up the stream, where the lower rocks form the surface. This formation is well exposed in this vicinity, forming often an irregular line of escarpment around the brow of the hill for many miles in extent, where enormous blocks, dislodged from the stratum, open lanes and passages between them and the main bed.

In the bed of the valley of Stony Fork, the impure calcareous rock near the top of the Ponent series sometimes shows itself. About 3 miles from the mouth on the E. side, a very ferruginous spring appears, depositing a large mass of brown ochre. A little above this spring an excavation was made in search of ore, and a band of small compact nodules, whitish within and coated with a brown crust, was found imbedded in a shale. After penetrating to a depth of a foot and a half, a copious influx of water arrested the digging. This band of ore is conceived to be a continuation of that already discovered in so many places in the Umbral red shales. The same band was found some years since, several miles to the W., on Pine Creek. On the W side of Stony Fork the red shale below the conglomerate is very ferruginous.

Between the layers of the conglomerate, and but a short distance from the bottom, was found a thin band of black shale, readily mistaken at first for the outcrop of a seam of coal. As it is somewhat continuous, though only 1 foot thick, it is desirable thus to mention its position, corresponding as it does with the small seam of coal everywhere underlying the conglomerate, and representing at this great distance E. the Sharon series of Mercer and Fayette counties to the W. and S.

Over the conglomerate on the same side of the stream, the ground rising 20 or 30 feet, a few pieces of kidney ore were discovered. Upon trial, the bed, however, proved to be thin and irregular, being a band in the brown sandstone. Signs of the same seam were met with in other places, in a corresponding position in the strata, but they nowhere gave promise of being productive.

At the mouth of the Second Fork of Pine Creek, the rocks dipping gently to the N., the Ponent series extends from the bed of the valley a considerable way up the hills, the conglomerate capping only the highest knobs, and no Coal-measures appearing above this along Pine Creek. The only chance we have of finding them is above the head of Elk Run, which enters Pine Creek a mile and a half above the mouth of the Second Fork. Here a bed of iron ore was opened a few years ago below the conglomerate, being probably the same found upon Stony Fork. It was mined for a short distance in, by a regular drift, and proved to be between 3 and 4 feet in thickness; the whole of which, however, is not ore, a portion consisting of imbedding shale.

On Big Pine Creek, about 4 miles above the mouth of the Second Fork, the rocks, previously nearly horizontal, dip S., bringing in the conglomerate on the summits of the hills, about 2 miles below this place on the E. side of the stream. This very shallow basin in the rocks will therefore, probably, not yield any coal along Pine Creek.

CHAPTER IV.

THE FOURTH BASIN WESTWARD TO PINE CREEK.

The third axis, which crosses the Tioga River between Covington and Mansfield, traverses the middle of the Wellsborough Valley as far as the Round Islands where it crosses Pine Creek. The Wellsborough Valley, as here referred to, includes not merely that lying under our view as we look down from the hill-top, one mile from the village on the Covington Road, but also the whole tract of hilly land, and bottom, about 10 miles wide, which lies between this ridge and the mountain plateau of the coal-basin on the N., now to be described. This interval is composed of the upper 300 feet of the Vergent series, some layers of which, particularly those adjoining the stratum of limestone above mentioned, are very rich in fossils. These rocks are thrown into a broad arch by the third great axis of the region. The hills lying at the base of the two mountain-ranges on the opposite sides of the valley, are composed in part of Ponent rocks, and show this formation much thinner on the N. than on the S. side of the valley: its precise thickness could be readily obtained; but a mile N. of Wellsborough it was not supposed to exceed 100 feet.

The Vergent series is not extensively developed where this axis crosses Pine Creek, and a satisfactory reason may be had by observing the W. dip of the axis itself. A few miles from Covington, distant about half a mile S. of the road, the top and sides of a hill, by their peculiarly regular and well-marked slopes and bends, show the dip without need of exposures. It plainly exhibits the dip of the strata within it to be about 70° W. by S. This hill is nearly upon the summit-line of the axis. Were it to continue W. with no modification or irregularity, the geographical level of two points on the same geological level would vary by nearly 10,000 feet. We must therefore conclude that at this point the axis has a sudden flexure downward to the W., while the superior height of the Vergent rocks upon Tioga River, above that which they attain on Pine Creek, proves that the axis, on the whole, slopes several hundred feet to the W. in that distance.

From the hills affording the view of Wellsborough above mentioned, facing N., one may discern a range of very high land, ranging at the nearest point within 5 or 6 miles of the point of view, and opened by three conspicuous gaps. One of these is that of the Tioga River; a few miles W. is a double one; and the third marks the issue of the Big Marsh Creek. The mountain is seen to continue to the W. of the latter along the N. side of Pine Creek, and is still cut transversely at intervals by the N. smaller tributaries of that stream.

From one of the hills, a few miles S. of the Cowanesque, we see looking S. the N. border of this same mountain-range; it is equally straight and regular in its summit outline, and gapped in fewer places. This mountain-chain is 6 or 8 miles broad, like the others already described, and is not only split down lengthwise to its base by Crooked Creek, but deeply furrowed by dozens of its tiny branches and their water-courses. This is one of the most curious facts observable in Tioga County, and well illustrates the influence of its geology upon the topography of the country. Not only do most of the streams head upon Axis No. 3, and flow N. to Big Marsh and Crooked creeks, and S. to the Second Fork, but in the valley N. of the mountain-chain,—we here mean the valley through which Axis No. 5 runs,—the streams head on that axis also, and flow down the N. and S. slopes into Crooked and Pine creeks and the Cowanesque. And we may say that it is in obedience to this general law that Pine Creek, in the upper part of its course, flows E., that is, along the centre line of the Fourth Basin, and not S.

The only point where we found coal, and evidently the only place where there is any likelihood of finding it, is at a low knob upon the N. side of the mountain, 2 miles up the North Branch of Crooked Creek, above its forks, and 9 miles from Wellsborough.

Here is a coal-bed overlaid by 20 or 30 feet of sandstone, its outcrop describing a wide circle about half a mile in diameter. Its thickness is not known.

Westward of this, between Long Run and Big Marsh Creek, the top of the mountain is capped in many places by this same bed of coal, about 2 feet in thickness. The conglomerate in the first position (near Wellsborough) does not deserve that name; one passes it in going up to the coal, and only recognises it by the steeper slope which it causes, and its proximity to the coal. It is about 60 feet thick, fine in its texture, and is underlaid by red and green shale, without the appearance of iron-ore. It is possible, however, that this coal-bed may be the one that underlies the main Seral conglomerate, in which case the latter cannot be said to be present on the mountain.

Upon Pine Creek this rock is a coarse and true conglomerate, and appears in bulk upon most of the hills N. and S. of Pine Creek going W. This part of the basin could not be well explored, because of the extreme wildness of its state at present, and more labour and an expensive outlay of time did not seem to be demanded by the very inferior value of its economical geology. Only one seam of coal is likely to be found upon a few spots on its highest planes, and that one is seldom worth the working.

CHAPTER V.

THE FIFTH COAL-BASIN W. TO THE GENESEE RIVER.

Upon the highest knob of the low mountain-land which bounds the broad anticlinal valley of the Fourth Axis on the N., within sight from Knoxville (a little village upon the Cowanesque at the mouth of Troup's Run), there is a platform of whitish sandstone, covering perhaps 50 acres, and from 10 to 15 feet in height. This platform probably conceals, and has protected, a remnant of the lowest bed of coal—viz. that just described in the last chapter as in a similar position.

The Seral conglomerate appears only as a well-marked terrace of coarse white sandstone, passing insensibly downward into Vespertine grey sandstones, as do the latter into Vergent flaggy grey and olive sandstones.

Of the Umbral Red-shale ore no traces were here observed; but 7 miles W. of Knoxville, on the top of a hill on the S. side of the Cowanesque Creek, upon the road which leads over to Mixtown Settlement, large blocks of white sandstone assert the presence of the Seral conglomerate, and on the S. side of the hill appear red and variegated shales, with small pieces of iron ore of poor quality, and not in abundance. It was in descending this hill, among the outcrop fragments of the grey Vespertine rocks, that a fine fragment of *Holoptychius* was found.

About 8 miles N.W. from the Big Meadows occurs a bed of iron ore, from which a large deposit of brown ochre has been produced. Much ore has been taken from this spot. The ore-band has not been fully developed; it occurs within 100 feet of the summit of the hill, lying probably below the conglomerate, though that rock does not appear. About 2 tons only of loose nodular ore have been excavated. 20 feet below this bed, a bench or broad terrace occupies the flank of the hill, embracing about 20 acres of surface; it is covered by a rich deposit of the bog-ore, to a depth averaging perhaps 2 feet. Higher on the hill a small seam of coal, 1 foot in thickness, occurs, which is of limited extent. Near the summit of the hill are indications of another bed of iron ore.

CHAPTER VI.

COUNTRY BETWEEN PINE CREEK AND THE SUSQUEHANNA WATERS.

The great rolling plateau of the Alleghany Mountain, in which Pine Creek and the Susquehanna River, with its numerous branches, cut their way 1000 feet below its general surface, has not, until within a few years past, received any contributions from the foreign or domestic centres of emigration. It remains almost what it was a century ago, an unbroken forest, tenanted by the panther, bear, deer, wolf, and fox.

The soil is cold, but produces excellent wheat—not, however, in heavy crops. The grasses are the natural staple of the cleared bottom-lands of Pine Creek.

Across this region the Jersey Shore and Coudersport Turnpike passes, ascending its S. escarpment, where Pine Creek issues from it, 4 miles from Jersey Shore. The ascent is 2 miles long; the whole distance to Coudersport, about 80 miles. For 68 miles of this road, at the time of our last visit in 1846, the traveller passed the doors of only six houses, while thirteen other families resided at greater or less distances from it, in the forest to the right and left. Three of these were Irish settlers living at the head of Chatham's Run, and holding correspondence with the world through Jersey Shore. Four others, the extreme E. families of the settlement, were upon the S. Fork of Kettle Creek, a settlement numbering, in 1846, thirty-three families, and communicating, by canoe navigation, through an uninhabitable gorge of 8 miles, or by "Boon's Road," 14 miles across the mountain, with the main Susquehanna, above Young-Woman's Town. In such a country, with the small means at our command, little could be accomplished beyond merely noting the general phenomena, sufficiently indeed, as in the end appeared, to enable us to announce the economical value of its geological contents.

A low ridge, perhaps 100 feet in height, called the Sandstone Ridge, and ranging from the head of Queen's Run E., upon the general table-land, terminates with a beautiful rounded and terraced end, at the turnpike near M. Focht's house, 11 miles from Jersey Shore, and 5 miles back from the edge of the mountain, if measured diagonally along the turnpike. Here, upon the turnpike, and marked by the bench in the ridge's S. side, is the outcrop of what is probably the only coal-bed in the region. Its outcrop is repeatedly marked upon the turnpike between this place and Mr Hearod's old settlement, 23 miles farther on. It is always seen to be covered by reddish friable shales. In many places it appears to be rather two beds than a single one, separated by several feet of intermediate rocks.

Mr Hearod's tavern is situated in the Third Basin, and the coal, 1 foot thick, was once opened upon his land. It outcrops in a well-marked bench upon the road, 1 mile N. of his house. Here, as in many other places, the disintegration of the Seral conglomerate produces a fine white sand, well adapted to the purposes of the glass-maker. It is said that, in sinking the well at Mr Hearod's clearing, coal of good quality, and 3 feet thick, was struck at a depth of 20 feet below the surface. This would show its place to be from 40 to 50 feet above the conglomerate.

The turnpike enters Potter County at its S. corner, and leaves it at its N.W., not far from Olean Point or Hamilton Village, in the State of New York.

After passing the N. outcrop of Hearod's Coal-bed before mentioned, one passes 8 miles over Vespertine sandstones, and also flats covered with a reddish irony soil, doubtless due in some measure to the presence of Umbral red shales. All this distance the land is very high, and gently rolling; but now suddenly commences a deep descent to the bed of Kettle Creek, by the valley of one of its tributaries, which excellently illustrates the sharp ploughing action of the denuding floods, which swept across the country, leaving it ravined and trenched as we see it.

The abrupt heading-up of such a valley upon the comparatively dead level of the table-land is remarkable, and may be compared with the ravines (on an infinitely smaller scale) effected in the soft banks of the streams of the sea-coast, by the yearly rain-drainage, wherever the cultivation of the soil had been neglected.

The third axis crosses the road between the forks of Kettle Creek, bringing in sight in its deep valley the upper rocks of the Vergent series.

After crossing the West Branch, the road rises again to the summit-level, and is made to follow for several miles the crest of a "hog-back," where the traveller looks right and left down two steep slopes into two parallel valleys, each many hundred feet below him. This is composed of Vespertine grey sandstone, excepting two long flats covered with the above-mentioned red soil, and two small unconnected patches of Seral conglomerate, which here seems to be a fine-grained white sandstone.

The conglomerate does not occur again on the road to Coudersport, although the latter keeps upon the high ground across the fourth axis, and into the Fifth Basin. There the road descends into the valley of the Alleghany River, where the upper mixed strata of the Vergent series appear upon it.

It will thus be seen that on this road there appears no sign of coal in the Fourth or Wellsborough Basin, although the mountains in that basin, at the elbow of Pine Creek, contain the lower bed, as does also the high land crossed by the road at Hearod's, in the next basin to the S. It remains yet to be seen if the coal appears where the basin is crossed by the Driftwood Branch of Sinnemahoning. The wildness of the country effectually prevented a nearer approach to certainty, though such might readily be obtained by a camping party.

CHAPTER VII.

FIRST BASIN TRACED FROM THE SUSQUEHANNA S. TO CAMBRIA COUNTY.

THE rocks along the Susquehanna River are the argillaceous sandstones forming the thick bands at the alternation of the Ponent and Vespertine series, dipping at a considerable angle to the N.W. At the mouth of Lick Run these give place to Vespertine rocks, having their usual character of a brown slaty sandstone, but containing a few bands of a silicious conglomerate, somewhat like the Seral conglomerate, though darker. Above this sandstone lie the Umbral red shales in two separate strata, alternating with a grey sandstone, referable either to the Vespertine or Seral series. The lowest of these red shales is a bed 65 feet in thickness, containing two seams of *iron ore:* one only about 6 inches thick; the other, 20 feet above it, being about 10 inches. The ore is apparently good, but probably not sufficiently abundant to be valuable.

A similar ore has been discovered on Queen's Run, 1½ miles N.E. of the Queen's Run Mines, where it promises a greater quantity. Between the two seams of ore occur buff-coloured and red shales. Overlying this red shale is a thick stratum of grey sandstone, analogous to the Vespertine grey sandstone, about 250 feet thick. This supports another thinner bed of Umbral red shale. At the mouth of Queen's Run the Vespertine sandstone contains a seam of fire-clay 4 or 5 feet thick, which is a little too sandy, but may be worth working, if mixed with a more argillaceous variety. At the mines on Lick Run the strata have been bored from the highest ground down to the upper bed of the red shale. At different points where this was done the strata do not precisely correspond. One of the most important of the beds, a seam of coal, is absent over a considerable extent owing to a dislocation in the strata, or to other causes not yet ascertained. In one of the knobs, where the position of the coal appears to be represented by slate and sandstone, we have the following section (see Fig. 357).

Soil, 21 inches. *Coal,* not under sufficient cover to be hard, 5 to 6 feet (here only 1½ feet). Fire-clay, 6¾ feet. Brown Slate, 5 feet. (*Coal* should here occur 19 feet beneath the brown slate, 6 feet thick, and containing 16 inches of slate, but it is absent). Dark slates and flaggy sandstones, 76½ feet. *Coal,* 2 feet 4 inches. Dark slate, 9 feet 7 inches. *Coal,* 3½ to 5 feet.

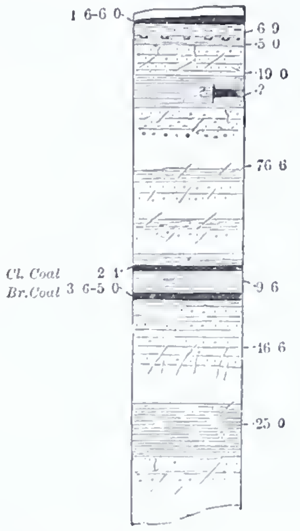


FIG. 357.—Lick Run, Farrandsville.

This is the lowest coal-bed of the basin, as it was mined by the Farrandsville Company for the use of their furnace, where it underwent the coking process without the aid of ovens. It was then sent by an inclined plane and railroad to the furnace at the base of the mountain. The second coal-seam in the ascending order was not worked, the coal being impure; but the third, where the ground is sufficiently elevated to embrace it, has been wrought to some extent, yielding a better coal than either of the other two. It is now, however, nearly exhausted. This upper coal-seam, lying usually near the surface of the highest ground, has generally an unsound roof, which unfits it to be mined. It measures commonly 6 feet in thickness. It is removed to expose the fire-clay which lies immediately beneath it, found to be of superior quality for the manufacture of fire-brick. This fire-clay, from 6 to 7 feet thick, is destitute of grit, and furnishes an admirable fire-brick. Under it lies a bed of shale, containing a layer of *nodular iron-ore* of no great purity or richness.

Beneath the lowest bed of coal slaty sandstone and shales occupy a thickness of 46½ feet, succeeded by 25 feet of red shales, this by upwards of 200 feet of grey sandstone, and this again by the lower bed of red shale. It is very remarkable that we nowhere find the rocks occupying the position of the Seral conglomerate, possessing the conglomerate character, while in every other neighbourhood in the same basin, as at the First Fork of Pine Creek and on the Tangascootac, as we shall show hereafter, this rock exists in its true type and features.

At Queen's Run the same beds of coal and fire-clay occur which we see at Farrandsville, with this difference that the uppermost coal-seam is there under an ample covering, and ranges over a tolerably extensive surface, being the only bed at present mined. Its thickness varies from 5 feet to 3 feet 9 inches. The coal is superior, and finds a ready market along the Susquehanna.

The *fire-clay* at this place is occasionally 8 feet thick. A bed of coal about 4½ feet thick occurs not far beneath it. This does not appear in the Coal-measures above Farrandsville. The other beds in the series are supposed to occur here, though their existence has not been positively ascertained. At the mouth of Queen's Run fire-bricks have been made to a moderate amount, and at Farrandsville on a more extensive scale.

The smelting furnace at Farrandsville is built of stone, lined with the fire-brick; it is 54 feet high. The diameter of the boshes was originally 17 feet, but was reduced to 13. A powerful steam-engine having 10 boilers, and estimated at 170 horse-power, when all are in action, propelled the blast. From the description given of the Coal-measures of Farrandsville, it would appear that they furnish neither iron ore nor limestone; hence the ore used in this furnace was brought from Montour's Ridge in Columbia County, being the fossiliferous ore of the Surgent shales. An inferior species was also procured on Larry's Creek from the lower beds of the Ponent series; the former was transported about 100 miles, the latter 23 miles. Limestone from Nittany Valley was used as a flux. The proportions of the materials employed in making one ton of cast-iron, in October 1839, were as follows:—

Coke, 6500 hogsheads, 2900 tons; Fossiliferous Ore, 3200 hgds., 1428 tons; Larry Creek Ore, 3500 hgds., 1562 tons; Limestone, 4500 hgds., 2009 tons.

After the furnace had been in blast some time the cast-iron produced was of a superior quality as a foundry iron, and the yield was about 50 tons per week.

The extreme horizontality of the rocks observable in ascending the Susquehanna from Queen's Run, is undoubtedly due to the dying down of one of the broad axes of Tombs' Run Valley, which crosses Pine Creek about 7 miles above its mouth, and passes under the turnpike W.

Tangascootac.—Passing to the W. side of the Susquehanna, the Coal-measures next appear on the Alleghany Mountain, on the S. side of the Tangascootac Creek. This stream runs nearly centrally along the basin for 5 miles, with a margin of comparatively broad and regular bottom-lands on each side. Owing to the greater amount of denudation in the lower part of the valley, the Coal-measures do not there occur; but higher up they expand over a considerable extent of country, and acquire a thickness of several hundred feet. The forest growth near the S. Fork is open, consisting of fine hard wood and scattering white pines, and the surface changes from the steep mountain acclivities seen nearer the river, to gently-rolling hills and extensive plains. The rocks along the valley of the Susquehanna for about 6 miles belong exclusively to the Vespertine series. At the mouth of the creek this formation rises nearly to the top of the Alleghany Mountain, and caps the hill on the N. side of the stream. The first appearance of conglomerate is where it covers the E. extremity of the Alleghany Mountain. Tracing it W. it gradually comes in at a greater distance below the summit, until, 3 miles from the river, the Coal-measures occupy the mountain-top, and the white pebbly sandstone of the Seral conglomerate lies under the summit, and crops out high up on the S. side.

The hills on the N. side of the Tangascootac do not reach the elevation of the Alleghany Mountain until we advance N. several miles, when a change of the dip to the S. brings up the lower rocks, but with an extremely gentle dip. Along the N. side of the creek the knobs are capped by Seral conglomerate as far up the valley as the forks. A little below this the Coal-measures first appear on the N. side of the stream, and finally, farther towards the W., they occupy all the high ground between the heads of the two forks, but no coal occurs to the N. of the North Fork, the hills there being capped by the conglomerate.

The most eastern coal-beds opened are S. of the First Fork, at an elevation of about 530 feet above the stream, which, in the course of 2½ miles to its mouth, descends 30 feet. The upper bed lies beneath a thick stratum of brown sandstone. It appears to be 4 feet thick, but at some distance in from the outcrop a fault causes it locally to be only 2 feet. The quality of this coal is excellent; it is underlaid by a bed of good fire-clay. There occur about 35 feet of other strata covering this bed over an area of perhaps 50 acres.

Another coal-seam, somewhat slaty, 3 feet in thickness, lies about 30 feet lower down, at no great distance under which is the conglomerate, forming a stratum nearly 100 feet in depth. This rock is here a fine sandstone, containing white pebbles, and disintegrates into a fine sand, well adapted for making glass.

The next openings are on the S. side of the creek, two miles above the forks. The upper bed occurs near the top of the hill; it is 4 feet thick, including some small seams of slate and fire-clay. Over it lies a soft and very tenacious slate-clay, 4 feet thick. The coal is good; it breaks into rectangular pieces, and contains much mineral charcoal, occasionally in seams nearly half an inch in thickness, showing the fibrous structure of the coal vegetation. It is beautifully marked by thin alternating lamina of dull splint and splendent glance coal. A bed, supposed to be the same, has been opened at a lower level in a N.W. direction, that being the course of the dip. At this latter place its total thickness is 4 or 5 feet, including 1 foot of dividing fire-clay.

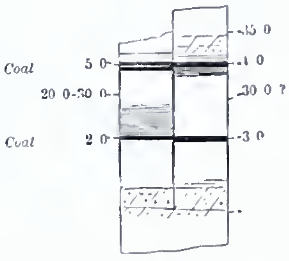


FIG. 358.—Tangascootac Creek.

Between 20 and 30 feet under this occurs another coal-seam, not well exposed, but apparently 2 feet thick; upon it rests 2 feet of fire-clay, and over that 1 foot of black slate, surmounted by more than 10 feet of blue slate. The rocks underneath the coal are entirely concealed, but the conglomerate cannot be far below.

On the S. side of the Alleghany Mountain there are two small *benches* near the summit, at some height above the steep slope, caused by the conglomerate. The lower of these contains the "brown rock," while the upper one probably embraces a bed of coal.

The hills N. of the North Fork constitute the N. margin of this coal-basin. They are higher than the hills around, being capped by the conglomerate. Between the N. and S. forks Coal-measures extend through the hills for some distance. Indications of *iron ore* present themselves in the Umbral Red Shales, in a ravine 2 miles above the forks. Between 5 and 6 miles from the mouth, the Coal-measures are within 75 feet of the beds of the streams, the hills rising about 250 feet higher. Further W., the surface becomes smoother, and the extent of country embracing the Coal-measures much greater. The distance across the basin, from the Alleghany Mountain to the hills N. of the North Fork, is apparently about 5 miles, but the actual area of the coal is more circumscribed, owing to the numerous valleys of denudation. In the district described, the indications of iron ore among the Coal-measures are unpromising.

This basin is prolonged across the head-streams of Beech Creek, and embraces the Coal-measures at Snowshoe and Philipsburg, which will now be considered, premising that, where the waters of Beech Creek interlock with those of Tangascootac, we find that the Coal-measures, hitherto forming a narrow strip along the S. Branch of the Tangascootac, gradually widen and recede from the mountain as we trace them towards the S.W. As the main stream of Beech Creek flows close to the N.W. foot of the mountain, we meet with none of the productive Coal-measures immediately on either side; its hills consisting of the sandstones of the Seral conglomerate, no coal nor any indications of it could be detected. The nearest outcrop of a coal-seam is one which occurs a little N. of the turnpike, and which is about 4 miles N.W. of the E. summit of the mountain. This coal lies between 60 and 70 feet above the top of the silicious conglomerate. The bed is 4 feet 4 inches thick, and contains a thin seam of slate. The coal, which is good, has been mined to some extent. It may be traced over a considerable range of country, by a bench or little terrace, which marks its outcrop near the summits of the hills. This indentation near the tops of the hills, rising and becoming indistinct at the edge of the coal-basin, disappears entirely about 1½ miles E.N.E. of Snowshoe. Three quarters of a mile N. of the spots where the coal is opened, we discern the smut, which marks the outcrop of the coal at "Lucas's Sugar Camp," where an excavation, formerly made, has now caved in, hiding the thickness of the coal. The report throughout the neighbourhood is, that the bed is 9 feet thick, and contains a band of clay 3 inches thick.

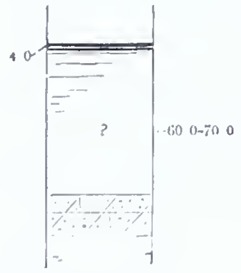


FIG. 359.—Beech Creek.

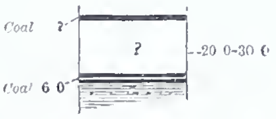


FIG. 360.—Snowshoe.

At the principal mine, which is on the turnpike, the coal-bed is 6 feet thick, including a layer of cannel coal, 6 inches thick, which runs through the middle. The roof here is also of slaty cannel coal, the body of the seam being, however, a beautifully brilliant and pure glance-coal, eminently suited to gas-making. It has a very sensible dip, inclining at an angle of several degrees, and to an unusual quarter, the N.E. and N. During the winter months coal in considerable quantity is transported from this mine to the country E. of the Alleghany Mountain. It is quite probable there may be one or two coal-seams beneath the main coal.

Overlying the seam just described, we find, where the hills are high enough, another bench or indentation, marking a coal-seam, between 20 and 30 feet above the former. This coal appears to be thin and unpromising. Iron ore, though in small quantity, occurs in a bed of brown shale beneath the first or lower coal-seam. This district is now about to be fully developed under the auspices of a Philadelphia Company.

In the country extending many miles N.E. from Snowshoe, we find a range of "highlands" along the heads of the N.W. Branches of Beech Creek, where the rocks next beneath the Coal-measures occupy the entire surface. These owe their elevation to the range of the first axis W. of the Alleghany Mountain. Like the rest of the high belts between the coal-basins, the surface of this region is rugged and stony, and ill adapted to tillage, while it is wholly worthless in mineral productions. The iron ore appertaining to the Umbral Red Shale may be met with in its usual position, just below the conglomerate, but possesses little value in a country so wild and destitute of coal. Indications of this ore appear in springs, depositing much bog-ore in a more accessible region lying S. of the turnpike. These occur between the two branches of the Moshannon, on the line separating the lands of Jacob Gratz, Esq., from those of the Portland Lumber Company, and again about a mile up the Big Moshannon, S. of the point where the "Indian Path" crosses it.

In this neighbourhood, the first coal which shows itself, as we pass W. from the ridge of the Alleghany, occurs in the hills along the Indian Path, near the mouth of the Little Moshannon. Two benches, marking two different coal-seams, were traced along these hills. Descending to the Little Moshannon, we meet the "brown rock," or the sandstone below the lowest coal-seam, finely exposed in the steep hill-slopes; and just beneath this, the coarser beds of the Seral conglomerate. The strata here dip 4° to the N.E. Indications of two good coal-beds were met with, where the "Indian Path" diverges from the Karthaus Road.

From a little above the mouth of the Little Moshannon, nearly to Philipsburg, no coal was discovered along the S.E. side of the Main or Big Moshannon, but at Philipsburg and S., up Cold Stream, coal occurs abundantly to within 1½ miles of the E. crest of the mountain. Six miles N.E. of Philipsburg there are indications of the Umbral ore upon the turnpike near the Moshannon; it lies under the coarse sandstone of the Seral conglomerate, which here constitutes the principal part of the hills. This ore is deserving of thorough investigation. Below this, on the Creek, springs depositing bog-ore are frequent. The red shale forms the bottom of the valley of the Little Moshannon near its mouth.

Philipsburg.—The principal mines wrought in the valuable district around Philipsburg are on the N. side of the Moshannon, opposite the village. The following section, compiled from measurements obtained at the spot, will show the number and relative position of the several beds:—

Covering rocks, thickness not great; Coal, 4 feet; Fire-clay, 2 feet; Calcareous Slate, 8 inches; Blue compact Shale, or indurated clay, 14 inches; Ferruginous Shale, 2 feet; Limestone, blue, ferruginous, 5 feet; Sandstone and Slate, 19 feet; Coal, good, 4 feet 4 inches; Fire-clay, 2 feet; Limestone, ferruginous, passing into iron ore, 2 feet; Sandstone, 16 feet; Coal, in Creek bed, 20 inches.—(See Fig. 361.)

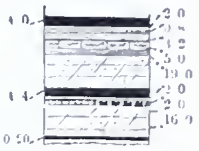


Fig. 361.—Moshannon, Philipsburg.

The middle coal-seam, represented in the above section, the only one now wrought, is mined to a considerable extent. It is 4 feet 4 inches thick, is of sound texture and excellent quality throughout, and will afford solid blocks of coal the whole thickness of the bed, and as much as 8 feet in length. The upper coal-bed of the section is stated to have been open formerly, and found 4 feet thick. From the low position of these beds, they must range through a wide extent of country. A shaft, sunk by us 2 miles W. of the above locality, brought to light a bed of coal, which is either the uppermost of the section or a still higher seam. The strata passed through will be seen from the following section:—

Olive Shale, 10 feet; Coal, 4 feet; Fire-clay, 2 feet; Decomposed ferruginous calcareous Sandstone, 3½ feet; Nodular Limestone in shale.

Throughout the country immediately N. of Philipsburg, a brown iron-ore is found loose in the fields; it is possibly derived from the ferruginous stratum mentioned in the section. The appearances at several localities are such as should induce a more thorough examination by the proprietors. One spot is on the turnpike, 3 miles N.W. of Philipsburg, and another 2 miles N. of the village. Examinations were once made at the latter place for hematitic ore, with the anticipation that it would prove like that of the limestone valleys E. of the mountain; but the operations were abandoned. A third locality is on Geerhart's Farm, near the Creek, 1½ miles S.W. of Philipsburg. Here loose pieces of limestone occur, associated with the ore. It is probable that all these exposures belong to the same part of the formation.

Coal occurs in abundance on the farm of John Goss, about 5 miles W.S.W. from Philipsburg, and 6 miles from the summit of the mountain. This is on the N.W. side of the Moshannon, 1½ miles S.E. of a high ridge, supposed to contain the first axis. The following section exhibits the geological position of the coal at this place:—

Coarse brown Sandstone; Black Slate; Coal too near the surface to be wrought, 7 feet; Interval, 20 feet, rock unknown; Coal, 2 feet; Interval, 15 feet; Coal, 6 feet 2 inches; Slate, 8 inches; Coal, 2 feet; Limestone, thickness unknown; Ore.—(See Fig. 363.)

The lowest coal-seam being separated into two beds, only the uppermost, which is 6 feet thick, is worked. It affords an excellent sound coal, free from sulphur and slate. This seam exhibits that tendency to a columnar structure which is so common a feature in the coal of all the basins immediately contiguous to the Alleghany Mountain. From its low position, in reference to the other strata, it ranges over a considerable extent of country. The uppermost coal-seam in the section occurs so near the top of the hill as to be too soft and dirty to work; from the same cause it does not spread over much extent of surface.

Coal occurs at two or three other places in this neighbourhood, showing a thickness of about 4 feet; but whether these localities belong all of them to one seam or to two, could not be ascertained.

From Philipsburg, S.W., the centre of the basin coincides very nearly with the general course of the Moshannon Creek, the strata on each side dipping gently towards the stream. The coal-beds along the S.E. side of the basin have been developed in the dividing-ridge between Cold Stream and Trout Run, called " Coal Hill." The lowest bed at this place has its outcrop about a mile and a half N.W. of the summit. It was found to contain 5½ feet of coal, resting on more than 6 feet of excellent fire-clay. The fire-clay lies within 6 or 8 feet of the top of the Seral conglomeritic rock, the " Brown Rock" being here absent.

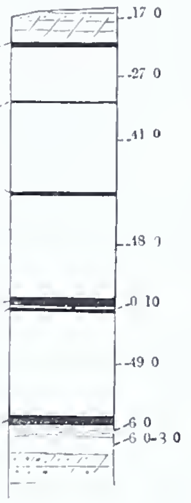


Fig. 362.—Coal Hill.

About 50 feet above this coal-bed occurs another, 9 feet thick, divided into two seams, by 10 inches of interposed slate, 2 feet from the bottom. The upper division, 6 feet thick, is alone worked. This coal is of sounder texture than most of that near the mountain, admitting of being mined in large square blocks. It is free from sulphuret of iron. This same bed has been opened 2 miles nearer to Philipsburg ; it and the lowest seam have been estimated to occupy as much as 4 square miles of surface in the country between Trout Run and Cold Stream. The thick upper bed here mentioned lies at a level 250 feet below that of the summit of the mountain at " Emigh's Gap," which is about 4 miles distant. In Coal Hill we have indications in the benches on the surface, of at least three other coal-seams—the smuts of only two of which are penetrated ; one proved to be 18 inches thick, and the other 4 inches ; no attempt was made to open the uppermost. These benches, or indentations on the sides of the hills, when distinctly marked, are unerring indications of the presence of beds of coal. The dip is about 5° N.W.—(See Fig. 362.)

Examinations were made in this vicinity in search of the iron ore of the Umbral red shale, some old openings giving promise that the ore might here be found. The excavations, commenced by ourselves, were prosecuted with much spirit by Mr Philips. Ore has been found in several spots accompanying the white and red clay, or decomposed shale, immediately below the grits of Seral, but the coming on of winter prevented the proprietor from determining the thickness of the deposit and quality of the ore. A rather thick ferruginous bed does occur here, but no specimens have yet come to hand, enabling us to pronounce upon its value. Should this locality of the Umbral ore prove productive, the place would unite many advantages for the establishment of iron works, lying near the fertile valleys E. of the mountain, and possessing an abundant supply of coal, excellent fire-clay and sandstone, a sufficiency of limestone and excellent timber, both oak and pine, and an ample water-power on Cold Stream. The country here abounds in excellent white pine, which is always best towards the heads of the streams. Cold Stream now drives a large sawmill and a forge. During the winter months, coal in considerable amount is hauled by the route of Miller's Gap, into the valleys S.E. of the mountain, where it is sold at the rate of fifteen cents per bushel.

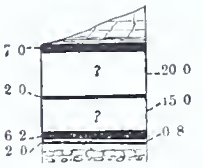


Fig. 363.—Goss's Coal.

On the Eastern Fork of the W. Branch of Muddy Run, on the county-line dividing Clearfield from Cambria, there occurs a large deposit of rich bog-ore, covering about 2 acres, and farther down the run, for a mile and a half, the springs in many places deposit the same ore in the form of a red ochre. This material is probably derived from the Umbral red shale, the surface on the Western flank of the mountain sloping rapidly to this point. A sandstone, corresponding in character to the Seral conglomerate, shows itself in the steep slope above the flats of the stream ; it is probably between 30 and 35 feet thick. Four other benches appear higher up, the second of these, ascending, is watered by a spring, and the third and fourth exhibit signs of coal and fire-clay. It is said that springs depositing bog-ore occur in many places along the summit of the mountain, in a position answering to that of the Umbral ore, and in some places in sight of the furnaces and forges in the valleys below.

Mount Pleasant.—In this neighbourhood we meet with numerous indications of coal and limestone, though the inhabitants have rarely been at the trouble to develop either. Only one coal-bed, 2 feet thick, has hitherto been opened, though the benches in the hills, and the smut exposed in the fields, imply the existence of three other seams.

Along *Clearfield Creek,* near Blain's Run and Turner's Run, coal, fire-clay, and limestone are abundant, and judging from the evidences of iron ore, enough of this mineral may possibly be found to make this a valuable locality. A little up Blain's Run there is a bed of good coal, 5 feet thick, near the level of the stream, and under it 14 feet of fire-clay, a part of which is well adapted for making stone-ware, and the rest fire-brick. A manufactory of the latter, owned by Mr Campbell, was established here, which yielded sometimes fifteen hundred bricks per day. Different varieties of good stone-ware have also been manufactured to some extent. Other seams of coal and indications of iron ore occur higher up in the same hill, above the coal already spoken of.

Farther down Clearfield Creek, a little above Porter's Run, there are three beds of coal, two of which are each 2 feet thick, the other 3 feet. There is also a bed of limestone 4 feet thick. Good kidney-ore, sometimes in one, sometimes in three bands, may be traced along the edge of the creek for several miles. The nodules are occasionally very large, but it is feared the quantity is insufficient to warrant mining. In this neighbourhood other beds of limestone were met with.

On the top of the hill near the Little Meeting-house, at Mount Pleasant, and occupying the highest position in the neighbourhood, is a thin bed of very impure limestone, of a brown and greenish colour, which breaks into square massive chunks. It is useless for any economical purposes.

Farther down, probably 80 feet, are slight indications of a coal-bed. It has not been explored.

Near the level of the run at Mount Pleasant is another bed of limestone, having above it a coal-seam, with fire-clay interposed. Above the whole is a bed of sandstone. The mineral characters lead us to suppose these beds to be Freeport Limestone and Upper Freeport Coal. If so, as the strata outcrop towards the Alleghany Mountain, another bed of limestone ought to be elevated in the trough; but the thick soil and detritus from the limestone hills beyond cover up its outcrop.

The limestone bed seen on the Ebensburg Turnpike, 2 miles W. from the summit, is believed to be the same as that of Mount Pleasant. Its mineral character is precisely the same, and it is overlaid by sandstone, but the coal and fire-clay are absent. Some 40 or 60 feet lower down is a coal-seam of inconsiderable thickness.

CHAPTER VIII.

SECOND BASIN TRACED FROM THE SUSQUEHANNA S.W. INTO CAMBRIA COUNTY.

THE rocks upon the Susquehanna from the mouth of the Tangascootac, are almost horizontal, but an axis (No. 1) may be observed crossing the river within 3 or 4 miles above the mouth of Rattlesnake Run. Here the upper members of the Ponent series form the base of the mountain, while the massive Vespertine grey sandstone stand out upon the precipitous sides, half-way up their slopes. For beauty and majesty the scenery is not surpassed by that of any other portion of the Union; while the clearness with which its features are defined will afford the student of diluvial agencies the amplest scope for minute and varied observation. The entrance into the main valley of innumerable side-drains, down the channels of which currents of every variety of volume, force, and direction have swept, complicates the problem, and at the same time greatly heightens the interest excited in its solution. The conflict and reactions of currents have frequently given birth to eddy-formed hills of the most regular and interesting shapes, widespread plateaus, scooped hollows in the mountain-sides, and lines of perpendicular escarpment, not simply displaying fine exposures for the fossilist, but features worthy of accurate investigation by the natural philosopher. The section above (Fig. 364) represents some of these cliffs in the neighbourhood of the entrance of the Rattlesnake Run Valley; the following (Fig. 365) shows a series of embouchures upon the same E. side of the valley, but higher up towards Young Woman's Town.

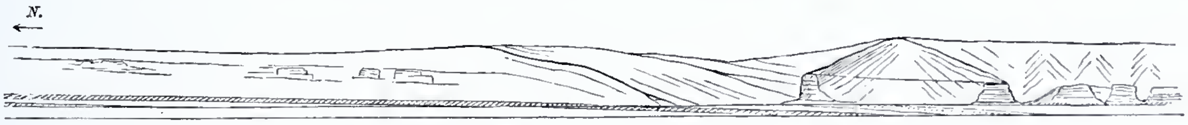


FIG. 364.—Section along the Susquehanna West Branch at Rattlesnake Run, showing the Vespertine Cliffs.

The grey Vespertine rocks, forming the cliffs shown in this Section, are about 50 feet thick, and everywhere superposed upon a stratum of conglomerate from 5 to 10 feet thick: this is first remarked upon the river at a spot just below Farrandsville. Among the alternations below this conglomeritic layer, as they are seen upon the road after it has passed Rattlesnake Run, going Northward, may be observed whitish flaggy sandstone with a marked Vergent lithological type, tinted red where weathered. Below this massive stratum occur, Red sandstone, 20 feet; Red shales, 20 feet; Massive red sandstone, 10 feet; contorted irregularly-deposited grey sandstone, 20 feet. Red sandstones in regular series, and very massive, follow the above as the main body of the Ponent series, and descend below water-level.

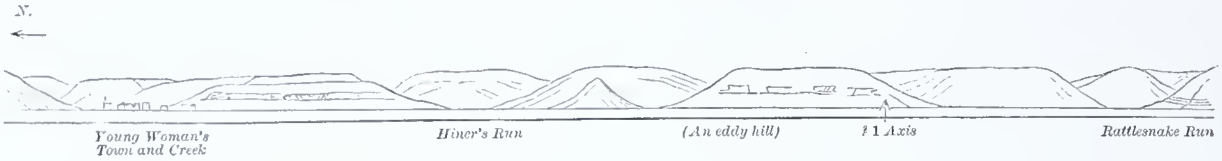


Fig. 365.

Coal is not found anywhere between Tangascootac and Young Woman's Town; but a company, owning lands about the head of Hiner's Run, are said to have been engaged in opening seams identifiable with those of Lick and Queen's runs.

Blocks of the Seral conglomerate occur everywhere along the river, especially through "the narrows," or dry road along the mountain-side below Rattlesnake Run, and above Farrandsville. The pebbles are larger than a common pea.

Upon the surfaces of this rock, lying beside the road, where the State Engineer Corps were engaged in blasting out the bed of the Erie Extension Canal, may be observed abundant sections of a species of silico-ferruginous concretions, sometimes concentric, and of all sizes from a diameter of 5 inches downwards.

Immediately N. of the river, above the mouth of Young Woman's Creek, the basin is very shallow, only a thin remnant of the Coal-measures capping the very highest hills. W. of the mouth of Kettle Creek, coal was once opened 3 miles from the river up Cook's Run, where it was stated the coal was 4 feet 2 inches thick, divided in the middle by 2 inches of slate. At a somewhat lower position in the hill, between the Seral conglomerate and the "brown rock," a bench occurs which may denote another coal, though none is at present known to exist here. A bed, corresponding to that above mentioned, is said to have been once opened on the S. side of the river, opposite the mouth of Cook's Run.

A little S.E. of the last locality the land rises by the cropping-out of the lower formations that fold gently over the anticlinal axis separating the First and Second basins. At the mouth of the Sinnemahoning the red and grey flaggy rocks reach a height of fully 150 feet above the water, but only emerge above the river-flats at the mouth of Cook's Run. The hills around the head of Cook's Run are very high, but consist of formations which forbid the hope of finding coal. The Umbral iron-ore may perhaps underlie the conglomerate on the hills, though the probability is slender of its being of sufficient thickness to be profitable.

From a point several miles below Karthaus, the Coal-measures in the river-hills are quite productive, embracing several bands of iron ore, limestone, and some excellent coal-seams; and near Three Runs we have, besides, promising indications of the ore peculiar to the upper Umbral red shales.

The coal-basin deepening gradually as we ascend the river, the large upper bed at Karthaus does not enter the hills until we pass above the neighbourhood of Three Runs. At the latter locality occurs a bed of coal 3 feet 2 inches thick, which has been opened, associated with a layer of *limestone* and one of *fire-clay*. Openings were once made into a coal-bed and band of iron ore on the S. side of the river, at a point high up in the hills; but the success of the exploration is unknown. Tracing the coal-rocks back from the river for 2 or 3 miles in this direction, we find them gradually rising until they appear finally only in the highest knobs, beyond which they are succeeded by the coarse beds of the Seral conglomerate, expanded over the elevated tract designated "Highlands" on the State Map.

On Birch Island Run, which enters the Susquehanna below Karthaus near the county-line, and 30 miles N.E. of Clearfield, several beds of coal have been developed on the property of Dr Lorain. The most important of these is opened on the hill between the forks of the stream. The bed is said, by those who proved it, to be 6 feet thick, and is regarded as the big Karthaus Bed. A still higher seam—4 feet thick—is found in the hill-tops, about 30 feet over the large bed. Iron ore is found associated with the shales enclosing it. Beneath the large coal—40 feet—a stratum of limestone 3 feet thick outcrops. On the same property farther W. two other coal-beds have been opened. They are reported as measuring 2½ and 4 feet respectively, and occupy a position lower in the series than the large seam.

At Karthaus the coarse sandstones and pebbly rocks of the upper part of the Seral conglomerate occupy the bed of the Susquehanna. The strata here dip about 5° towards the N.W., and preclude therefore any hope of finding the *iron ore* associated with the upper layers of the Umbral red shales. At Three Runs lower down the river the gentle rising of the strata may bring this part of the series into view, as already mentioned. The ore was here sought for just previous to the abandonment of the enterprise at Karthaus. A still more suitable spot will be on the S.E. side of the river, directly opposite the Karthaus Mines, on a small run divided from the river by two knolls. Here the conglomerate forms a perpendicular wall 25 feet high, the stratum dipping at an angle of 5°. The Umbral iron-ore should be searched for immediately at the base of this rock. Mr John James, the chief miner of the Karthaus Furnace, when it was in operation, compiled with considerable care a general section of the strata from the water-level to the summits of the hills near the furnace. This, with a few trivial additions to the column, is as follows:—

Slaty Sandstone (up to the summit of the hill, 565 feet above the river) said to contain a coal-bed 2 feet thick, 79 feet. Black Slate, 1 foot. *Coal* (elevation, 479 feet), 6 feet; fire-clay, poor, 2½ feet. Brown Sandstone, 45 feet. *Coal*, 10 inches; fire-clay, 2 feet. *Limestone*, silicious, 3½ feet. Shale, 1 foot. Brown Sandstone, 26 feet. *Coal*, 3 feet. Slate, 1½ feet. Grey Sandstone, 37 feet. *Coal*, 3 feet 2 inches; shale, containing 26 inches of good kidney-form iron-ore (elevation, 345 feet), 11 feet. *Coal*, 1 foot. Brown Sandstone and Slate, 21 feet. *Coal*, 1 foot; slate, 3 inches. *Coal*, 2½ feet; fire-clay, 2½ feet. Brown Sandstone, 35 feet. Coal, 1½ feet; fire-clay, ferruginous, 3 feet; shale, containing 25 inches of good iron-ore, called the "red ore band" (elevation, 268 feet), 11 feet 9 inches. Shale and slates, 22 feet. *Coal*, 1 foot. Sandstone, "the Brown Rock." *Coal*, thin. Seral Conglomerate, down to the river, 240 feet.—(See Fig. 366.)

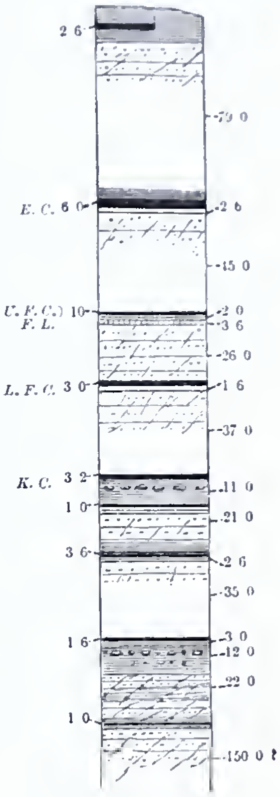


Fig. 366.—Karthaus.

There are in all 10 coal-seams of greater or less size in this part of the basin. The thick bed near the top is the only one hitherto mined. Lying near the summits of the hills, it does not, in the immediate vicinity of the furnace, occupy more than about 43 acres, though it enters a few small knobs to the N. and to the S.W., where the covering strata are thin. This bed is altogether 6 feet thick, but this includes 1 foot of inferior coal, near the top, which is not mined; the remainder of the seam consists of very excellent coal, adapted to making a superior coke. Lower down in the measures occur two important beds of iron ore. One of these, at an elevation of 345 feet above the river, is estimated to contain in all 2 feet of good blue kidney-ore in 11 feet of shale. The other stratum lies at an elevation of 268 feet. It also exhibits about 2 feet of good kidney ore in a stratum of shale less than 12 feet thick. This band is locally called the "red ore," and is of a different variety from that above it; they are both of excellent quality.

The limestone of this neighbourhood is for the most part inferior; only one bed of it, 3½ feet thick, occurs in the series. Besides the thick upper coal there are three others of a size suitable for mining, one of which is 3½ feet thick, and the two others each 3 feet; but none of these supply as pure a coal as the main seam.

Nine miles above this, on the river, the "red ore" has been found, and is stated to be thicker than at Karthaus. Three miles higher up there occurs a bed of coal near the summits of the highest hills, which measures 4 feet 4 inches in thickness; this, there is some reason to suppose, is part of the main Karthaus seam. Between the two localities mentioned appears a bed of limestone. In this neighbourhood the Seral conglomerate and sandstone occupy a position near the flats of the river. The Coal-measures spread but a moderate distance from the river on either side, the underlying conglomerate rising out and capping the hills everywhere from 3 to 5 miles from the river.

Much difficulty was experienced in the district around the town of Clearfield in identifying the coal-seams of neighbouring localities, and after close investigation, aided by frequent diggings, the stratification remains quite obscure.

The largest and best coal-seam in this division of the basin is that on the property of Mr Thomas Reed, near the bridge over the Susquehanna, two miles from Curwinsville. It lies between 80 and 90 feet above the river, dipping at a considerable angle to the N.W. The coal-bed is here 3 feet 6 inches thick. We have been told that 100,000 bushels of this coal have descended the Susquehanna to Harrisburg. It forms an excellent fuel, as it contains but little sulphur. Like most of the coal-beds of the S.E. bituminous basins, it affects a species of columnar structure, being traversed by innumerable vertical fissures which render it somewhat friable. For its composition consult the chapter of analyses.

Near Curwinsville a coal-seam has been opened about 70 feet above the river, upon the hill-side, by William Irvin. The bed measures from 24 to 30 inches, but is not considered good. The same seam has been wrought by Isaac Bloom, a mile lower down the river. Here the coal is much better, and is only 20 feet above water-level. Between these two points, at Holden's, the same seam is 40 feet, and on Reed's land, 1½ miles from Curwinsville, it is but 12 feet above the river. These facts indicate a decided E. dip of the coal.

The next workable seam, the equivalent of Reed's Bed before mentioned, is perhaps 100 feet above the former. It has been opened both above and below Curwinsville on the higher river-hills. The nearest mine is that of P. Carns, one mile S.E. of the town. The seam at this point measures 3 feet 3 inches, including a band of slate, the usual companion of the bed, 2 inches thick and 9 inches from the bottom. Higher up the river it has been opened by Dr Hoyt, and by Mr Bloom, from whose mines large quantities were sent down the river in former years, and by others 4 or 5 miles higher up it. Underneath this coal is a bed of limestone 3 or 4 feet in thickness.

The following is a section of the coal strata in the vicinity of Curwinsville, compiled by estimation:—

Unknown strata in the highest hills, 100 feet; Coal, 3 feet 3 inches; Fire-clay, 2 feet 6 inches; Limestone, 3 to 4 feet; Shale, including two thin layers of coal, 25 + feet; Unknown strata, 75 feet; Lower Coal, 2 feet to 2 feet 6 inches; Sandstone, 50 + feet; Shale, 25 feet to river.

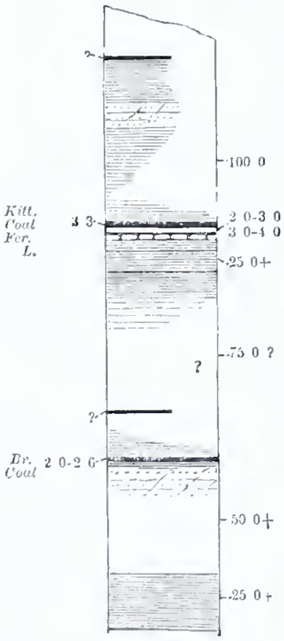


FIG. 367.—Curwinsville.

One and a half miles above Curwinsville, on the river, an old salt-boring is said to have penetrated a 6-feet bed of coal, at a depth of 100 feet. This stratum should be perhaps 80 or 90 feet below the river at the town.

High on Anderson's Creek Hill, about 2½ miles W. of Curwinsville, a coal crops out upon the turnpike. About 40 feet below this are indications of iron ore. A thick covering of debris prevents a close inspection of the strata upon this steeply-escarped hill-side.

On the N. side of the river, three-quarters of a mile above the town of Clearfield, occurs a stratum of fire-clay, of good quality, and 8 feet thick. Its position is a few feet above the river-bank. Oolitic iron-ore, seemingly of good quality, abounds in the upper part of the fire-clay, 2 feet of which contains about 1 foot of ore. A layer of similar oolitic ore, supposed to be the same, exists on Clearfield Creek, near the water-side, at the point of the Long Bend, amounting to nearly 2 feet of ore-balls in close contact. In the steep hill above this bed several seams of coal have been opened by Joseph Irwin, and the following strata are developed, as shown also in the accompanying vertical section (Fig. 367):—

Hill-top, 20 + feet; Coal smut, 0; (F.) Limestone, nodular, 0; Slaty sandstone and shale, 100 + feet; (L.F.) Coal, 18 inches; Fire-clay, 2 feet; Sandy shale, 25 feet; Compact obliquely-bedded Sandstone, 25 feet; Slate, 25 feet; (Kitt.) Coal, 8 inches; Slate, 5 feet; Limestone, 6 to 7 feet; Calcareous iron-ore, 2 feet; Sandy shale, 60 feet; Coal, 4 feet 6 inches, in two benches, the lower pyritous; Fire-clay, 4 feet; Slaty sandstone, 100 + feet; Coal 1 foot 6 inches; Slate with ore nodules, 12 feet; Coal, 6 inches; Slate, 3 feet to river at low water.

The only coal-bed of the above series opened for mining is the large one beneath the thick limestone. The limestone is quite pure, and burns to a good lime.

At the town of Clearfield a seam of good coal is wrought to some extent on the land of Mr Moore. It lies between 40 and 50 feet above a stratum of sandstone that occupies the bed of the river, and measures 2 feet 10 inches in thickness. The outcrop of another shows itself near the top of the hill, a mile S. of the town; this seam has nowhere been accurately developed. On the hill-top, E. of the town, a coal measuring several feet, is said to have been opened years ago. Two small beds are found below Mr Moore's, but are unimportant. No limestone has yet been detected. Moore's coal-seam is conceived to be the same with Owen's Bed, 2 miles up Clearfield Creek, where the coal is 3 feet thick, and of excellent quality. Over it are the indications of three other seams. It has been mined in another place, 3 miles up the creek, where its thickness, however, only amounts to 20 inches. Though several other coal-beds occur here, this lower one is the thickest thus far discovered.

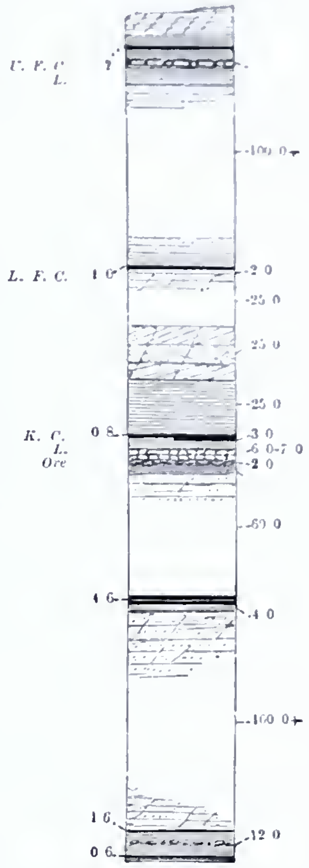


Fig. 368.—Clearfield Creek.

Besides the band of *iron ore* already noticed, several varieties of this mineral occur along Clearfield Creek. A rather peculiar, rough-looking ore, in large masses, some of them more than 100 pounds in weight, strew the surface of a tract of land lying a mile S. of the old turnpike. The mineral is heavy, but evidently not very rich in iron. A somewhat similar ore, possibly a part of the same bed, is to be seen on the E. side of the creek, at Beer's, where, though the surface-indications are encouraging, the quantity of the ore has not been proved. A peculiar compact shale or indurated slate-clay, of a bright blue colour, accompanies these ores, and is likewise found in association with another variety, 3 miles up Little Clearfield Creek. Here the shale, which is 12 feet thick, is less blue; scattered through it are small balls of ore. Beneath this is a considerable quantity of a coarse ore, in very elongated, somewhat cylindrical masses, like bars of pig-metal. It does not appear to be rich. On the old turnpike, near the tenth milestone W. of Philipsburg, appear two seams of good kidney-ore, requiring further digging in order to determine their value. On the new turnpike, near Roaring Run, a spring issues from immediately beneath loose masses of conglomerate, and deposits the red oxide of iron in a large bog. This spring forms a stream which propels Bloom's sawmill.

It is probable that we have here the line of contact of the Seral conglomerate with the Umbral red shales, and the presence of the usual band of ore at that place in the series.

Between Little Clearfield Creek and Mount Pleasant, the whole country consists of Coal-measures, none of the lower formations showing themselves in the position of the anticlinal axis, which elsewhere separates the First and Second basins. The chief feature, indicating the existence of an anticlinal axis between Philipsburg and Clearfield, is a high dividing-ridge, where, however, none of the lower rocks make their appearance. The obscurity in the outcrop of the strata along Little Clearfield Creek prevented our ascertaining clearly the stratification in that neighbourhood, to determine which would have required more time than we had at command.

This valley shows several good beds of limestone and some coal. At Mr Wright's, above Porter's Run, there are three coal-seams, two of which measure each 2 feet, and the other 3 feet thick. There is, besides a bed of limestone 4 feet thick, one, and in some places three, layers of good kidney-ore, lying in shale, which can be traced along the banks of the creek for several miles; the lumps are occasionally very large, but the whole quantity hardly sufficient to pay for mining. Going from Mount Pleasant towards Curwinsville, a limestone and an overlying coal vein, separated from each other by only a short interval, are seen in many places. It is supposed to be the Freeport Limestone, with its Upper Freeport Coal, and is undoubtedly the same bed with the one near the run at Mount Pleasant.

Near Curwinsville these strata occupy a higher level, being somewhat nearer to the second anticlinal axis.

According to the section made at Karthaus, the lower ferriferous limestone is wanting in that locality, as the bed of limestone noticed in that neighbourhood is estimated at 178 feet above the second great Coal-measure sandstone, which is precisely the position for the Freeport Limestone.

CHAPTER IX.

THIRD BASIN, FROM THE SINNEMAHONING SOUTHWARD INTO INDIANA COUNTY.

Between the Karthaus Hills of Coal-measures, in the Second Basin, and those of Bennett's Branch, in the Third, there passes a wide tract of elevated barren country, consisting of the coarse rocks of Seral conglomerate, which are here lifted to the surface by a broad and flat anticlinal axis. This axis of elevation, dividing the two coal-fields, crosses the E. Branch of Sinnemahoning a few miles above its mouth; then, curving gently Southward, it passes the main Sinnemahoning at the mouth of the Driftwood Branch, to range in a W.S.W. direction, through the high land dividing the waters of Clearfield Creek from those of Bennett's Branch. The belt of country immediately along this line presents few mineral features of importance. The Seral sandstone and Conglomerate cap the highest hills. Indications of iron ore occur in a few bog-ore springs, visible near the Sinnemahoning; but the great height and steepness of the hills, at the very summits of which it must lie, would render the ore, even if abundant, difficult of access.

The synclinal axis marking the middle of the Third Coal-basin crosses the E. Branch of the Sinnemahoning, about 10 miles above its mouth, and the Driftwood Branch at the same distance from its outlet, following the course of the stream. On the W. side of the Driftwood Branch one bed of coal has been discovered and opened near the level of the highest lands. A body of productive Coal-measures may possibly exist between this and Bennett's Branch, though, from the obvious shallowness of the basin here, the existence of such appears improbable. The country is excessively wild and rugged. The apparent extension of the Coal-measures for 5 or 6 miles N.W. of Bennett's Branch, up Hicks' Run and Trout Run, is a matter which claims some attention on the part of the proprietors of lands in this quarter.

At *Caledonia*, on Bennett's Branch, the basin becomes productive, the stratification embracing coal, iron ore, and limestone. This place is on the main stream, about 6 miles above the mouth of Trout Run. The hills on either side attain an elevation of about 550 feet, which they preserve for 3 or 4 miles back from the stream. On the S.E. margin of the basin, the rough rocks of the Seral conglomerate are visible on the Karthaus road, 4 miles S. of Bennett's Branch, dipping gently to the N.W.; and this dip continues to the N. side of the stream, the Vespertine strata, 2 miles above Trout Run, showing an inclination of nearly 5° in that direction. This N. dip, however, must soon change; for on Wolf Run, between 6 and 7 miles N.W. of Bennett's Branch, the coarse rocks of the Seral conglomerate again rise in the contrary direction, and cap the higher hills that bound the basin on the N.W.

Although the conglomerate at Caledonia (Warner's) lies but little above the flats which border the stream, yet 4 miles lower down the valley, in a N.E. direction, the subjacent Vespertine rocks appear at least 200 feet above the level of the water. This is due chiefly to the gradual ascent of the basin in that direction, and slightly to the fall of the stream; hence the probability of finding only a very limited amount of Coal-measure still further to the N.E., on Trout Run and Hicks' Run.

In the grey slaty Vespertine sandstones there occurs a bed of inferior sandy limestone about 4 feet thick. This contains many fossil shells and other marine remains, including those of one or two species of fishes. Associated with this limestone we find many little yellowish balls of excellent iron-ore. Between these and the Seral rocks we meet with indications of the bed of iron ore everywhere so prevalent in Umbral red shales, which formation itself seems to have thinned out. Up a little run, to be seen 1½ miles below Caledonia, we find a deposit of the soft bog-ore, derived, as usual, from springs flowing out of this part of the strata. We discovered a fine natural exposure of the bed of hard ore about 1½ miles above Caledonia, on the edge of Bennett's Branch. At the latter place the current has cut away the loose rock and covering soil, leaving the ore in view under the overhanging Seral sandstone, the bottom of which is within 8 feet of the water. Immediately beneath the sandstone lies 1 foot of black shale, and under this 3 feet of brown shale, containing scattered nodules of the ore, underlaid by a solid bed of the ore, forming, with a very little shale, a bed between 3 and 4 feet thick. This overlies a band of fire-clay. The ore somewhat resembles that found at Astonville, and described in my fourth Annual Report. A recent slide of earth and loose rock, somewhat concealing the layer, prevented our ascertaining its thickness with perfect precision.—(See fig. 369.)

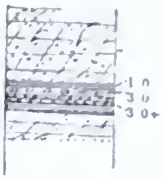


FIG. 369.—Caledonia.

The Seral conglomerate, the exact thickness of which was not satisfactorily determined, varies from a moderately coarse sandstone to a rough quartzose conglomerate in which the pebbles are occasionally larger than a turkey's egg. Large masses lie loosely scattered in great abundance: they present blocks of all sizes and every degree of relative fineness of texture, and admit of being easily split into fragments adapted to almost any building purpose. The whole stratum is probably about 100 feet thick, its lower edge, at Caledonia, occurring about 40 feet above the level of the stream. Above its top, the strata, which should contain coal, offer no exposures throughout a thickness of many feet. Near the head of a small stream, 4 miles below Caledonia, the upper edge of the sandstone is caught, lying about 300 feet above the flats; and very near this is a bed of compact yellowish shale, 4 feet thick, externally somewhat resembling a limestone. In no other place was this bed or any other visible near the top of the Seral conglomerate. The first stratum met with in the ascending order was a dark-blue shale, which occurs about 40 feet above the conglomerate. We had some reason to suppose that the interval contains a bed of coal. From the level of this shale upward, a tolerably minute section of the strata was procured by the aid of a pick and shovel, and the results contrasted with observations made in adjacent ravines and gorges. Some of the beds thus developed were found exposed on Warner's Run, and other thin layers were detected on Mead's Run, lying a mile to the E. From these various data the following somewhat detailed section of the rocks has been compiled. The more complete portion of the section terminates at the great bed of sandstone, 100 feet thick; but we have introduced several of the overlying beds in the order in which they were observed ascending the high lands N. of the sources of the above streams:—

White Sandstone, coarse, approaching a conglomerate, 50 feet. Coal, indicated by a bench, 0. Yellowish Sandstone, 40 feet (a bed of *Limestone* either above or below this stratum). Brown Shale, thickness unknown. *Coal*, 2½ feet (opened at Bockaway's on the turnpike); fire-clay, 6 inches. Sandstone, grey, slaty, with some interstratified shale, 100 feet. Black and dark shales, containing kidney-form iron-ore, 20 feet. *Coal*, 3 feet (upper 6 inches slaty); fire-clay, 1½ feet; fire-clay blue, good quality, upper part containing many iron nodules, 8 feet. Ore Stratum, with fire-clay (in all 3½ feet), comprising—Oolite iron-ore, 3 inches; blue clay, 12 inches; oolite ore, 6 inches; blue clay, 6 inches; oolite ore, 3 inches; blue clay, 12 inches, upon compact shale, blue and yellow, resembling externally a limestone, its upper part containing oolitic iron ore, 8 feet; olive shale, containing shelly ore, 8 feet; sandstone stratum, 1 foot; shale, with abundant ore, lower part massive and siliceous, 45 feet; olive shale, 15 feet. *Coal*, 1½ feet; blue slaty sandstone, 5 feet. *Limestone*, 10 inches; clay, 12 inches; *Limestone*, 3 feet; fire-clay, 1 foot; dark shale (with ore in its lowermost 4 feet), 10 feet; olive shale, 2 feet. *Coal*, inferior quality, 1½ feet; black shale, 3 feet. *Coal*, good, 5 feet; black shale, 2 feet. Sandstone, 10 feet; black shale, 4 feet; sandstone and olive shale, with nodules of iron, 30 feet. *Limestone*, 4 feet; sandstone, 10 feet; blue shale, 6 feet.

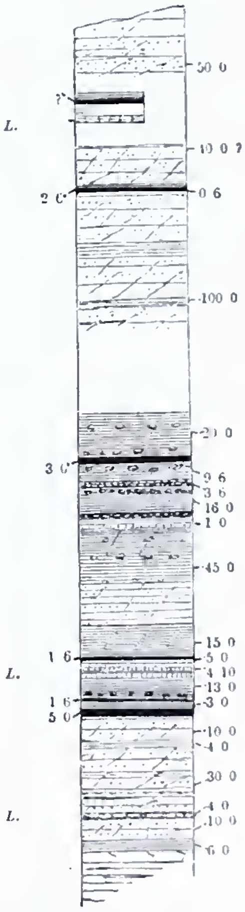


FIG. 370.—Bennett's Branch Section.

In the accompanying Section (fig. 370) names are given to all the coal-beds, but these must not be implicitly accepted.

On several of the adjoining runs, the iron ore has been dislodged from its shale in great abundance, and the indications are such that we believe it might be profitably mined in several drifts on the same stream. On the Clearfield Road, one mile from Caledonia, there is an exposure of iron ore on the road-side, but the exact place in the series occupied by this section has not yet been ascertained. It has been thought to be the same band as the "red ore" of Karthaus. Its position is not far above the upper edge of the Seral conglomerate. It consists of balls of heavy ore imbedded in shale, one-fourth of the lower 3½ feet of which consists of the ore. The excavation made to expose it evidently did not bring the whole of it to light.

The 5-feet bed of coal was discovered and opened by us where the above section was made, but we afterwards ascertained that it had been uncovered on other streams. This seam, consisting of sound coal without any slate, measures in one place 5 feet 2 inches in thickness. The lower limestone is blue, but it is not compact or close-grained. The upper limestone, probably the best of the two, is less blue, and of a finer texture. The blue and yellow compact shale, somewhat resembling a limestone, is a curious layer; it is often variegated, resembling occasionally a breccia, and is susceptible of a good polish.

Iron ore occurs abundantly in the shales above the second limestone; but in consequence of the difficulty we encountered in opening these beds and ascertaining the exact quantity of ore, we cannot venture to say more than that the indications are very promising. The quantity of the oolitic ore is considerable. The fire-clay on Mead's Run is a rather thick bed, and resembles precisely that worked at Farrandsville. The 3-feet bed of coal, containing in its upper part 6 inches of cannel coal, supplies a fuel much esteemed by the blacksmiths: besides occurring at this locality, it is found 4 miles N. of Bennett's Branch, at a spot one mile E. of the turnpike. In the upper part of the Coal-measures we met with one or more beds of fossiliferous limestone.

The facilities for mining the iron ore, coal, and limestone, in this neighbourhood, are certainly considerable; and these minerals all lie convenient to an ample water-power, which might be derived either from Bennett's Branch or Laurel Run, affording, if necessary, a fall of 50 feet, and water enough for extensive ironworks. The iron might be conveyed to market by the Susquehanna on rafts, the timber of which will pay, it is thought, all the expenses of the transportation. But these could only run during the spring, and occasionally in the summer, in times of freshet. During the winter, it is said, there is good sledding along the river on the ice. To reach a western market, it would be requisite to haul the metal about 20 miles upon a pretty good road to the Clarion River, whence it could be sent in rafts and arks from Ridgeway to Pittsburg. The neighbouring country is capable of maintaining ultimately a considerable population.

The basin of which we have here been treating extends to the S.W. up Bennett's Branch. It was found to be rich in coal and limestone for 10 or 12 miles above Caledonia. But the natural exposures of the strata near the sources of the streams are very few. The basin, both on the N.W. and S.E. sides, is bounded by high barren table-lands, in belts about 5 miles wide, capped by Seral conglomerate. The ridge of high lands on the N.W. is called Elk Mountain. A few of the knobs on the flanks of these broad ridges probably contain one or more of the lower coal-seams.

Coal-measures are found nearly 4 miles W. of Caledonia upon the flank of Elk Mountain, where it is crossed by the Ridgeway Turnpike. The lower strata outcrop, near the fork of the road leading from the turnpike to Winslow's, at the mouth of Trout Run. In the hills upon the latter stream, coal has been opened above Winslow's; and even as far as Spring Run, it is said to be found flanking the third axis.

The country above Luthersburg will be described at the close of the next chapter.

CHAPTER X.

THE FOURTH BASIN SOUTH-WESTWARD INTO JEFFERSON COUNTY.

The Third Axis, bounding this basin on the S., crosses the Driftwood about 7 miles below Portage (Emporium). Here it caps all the hills with Vespertine sandstones. But a little N. of it some remnants of Coal-measures encircle the heads of a few little streams, and contain one bed about 50 feet over the conglomerate, yielding 4 feet 9 inches of tolerable coal, with a seam of slate, 1½ inches thick, running through its middle. Its roof is blue slate, and a stratum of sandstone 30 feet thick caps the hill. No limestone is visible. Everywhere along the high edges of the hills (which are here, and N. above the Portage, between 500 and 700 feet high), under the bench of Seral conglomerate,—or white sandstone rather, for that is its character here—there issue springs depositing vast quantities of bog-ore. It being but 15 miles from Caledonia, where the Umbral red-shale ore is so thick and abundant, the reasonable supposition is, that up the Driftwood, in this neighbourhood, the ore might be obtained in large quantities.

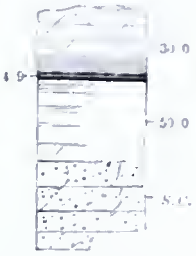


Fig. 371.—At Emporium, 3d Basin.

North of this, as far as Portage, the hills are capped by Seral conglomerate. Three miles above Portage, West Creek enters the Driftwood from the W. In its valley ranges the N. boundary of the basin, axis No. 4, which brings up about 20 feet of Vergent rocks above the water-level, while the rest of the hill-side is made up of Ponent, but principally of Vespertine rocks. The Ponent formation is here rapidly thinning toward the N.W. across the basins.

The S. dips are everywhere about 5° N. of the S. axis; a Vergent stratum exhibits a dip of 6° to the N.N.W.

The Vespertine sandstones are about 400 (?) feet thick upon the Driftwood at the third axis.

Five miles N.W. of Bennett's Branch, ranges the summit of the high ridge designated on the map of the State as the Elk Mountain. Its elevation above the stream is not far short of 600 feet. The sandstone and conglomerate rocks, constituting the Seral conglomerate, here reach the surface, and form a rough and stony belt nearly 4 miles wide. The rise of the strata on the N.W. side of the Bennett's Branch Basin is tolerably rapid. About half-way across the broad anticlinal elevation of Boon's or Elk Mountain there occurs a considerable exposure of red soil, derived either from the Umbral red-shale and iron-ore stratum, or from the upper layers of the conglomerate—which latter formation, however, it can hardly be.

The fourth axis, which separates the Fourth and Fifth basins, after indicating its presence, as we have shown, upon West Creek, by elevating strata beneath the Coal-measures, leaves the valley of that stream, and ranges S.W. At Roselay the Seral conglomerate strews the surface over a broad expanse. The precise line of the axis is not easily defined in the wild country through which it passes to the S. of St Mary's, but it again appears upon the Centreville (Kersey) and St Mary's Road, at the crossing of Laurel Run. In this neighbourhood the Seral conglomerate occupies a place low in the hills upon the water-courses, and the Coal-measures are cut out over a comparatively narrow belt. We find the conglomerate cropping on the Centreville and Ridgeway Turnpike at the forking of the Brandy Camp or Brookville Road. On the latter road, nearly a mile S. of the turnpike, it may be seen dipping 10° S.E. into the Fourth Basin, or that of Little Toby Creek. To the W. of this line, towards Ridgeway, the surface is sheeted by that formation, which gently undulates into the Fifth Basin. There is, therefore, but little hope of finding valuable coal-strata, except on the higher grounds, where the conglomerate has disappeared S.W. of the fork of the Brandy Camp Road. But a small part of the Seral conglomerate stratum, along the line which we have been tracing, is pebbly, the chief portion being a coarse yellowish sandstone, marked with ferruginous streaks. At the upper edge of the stratum is a layer of compact white silicious sandstone. This bed, when it disintegrates, forms a remarkably pure white sand, which in some places is found in great abundance.

The centre of the Fourth Basin coincides with the general course of the Little Toby Creek (unnamed on the map) S.W. into Jefferson County. On the N.W. we have already traced the boundary of the Coal-measures; on the S.E. they extend high on the flank of Boon's or Elk Mountain.

Several sections of the strata in different parts of the basin were obtained, some of them embracing an almost complete series of the rocks and included minerals. In these researches we ascertained the existence and position of two valuable beds of limestone, which we believe to be continuous over a considerable area of country, together with several impure bands found to be destitute of fossils, and the continuity of which we consider doubtful. The sections are compiled from observations, made in one case on the E. side of Brandy Camp Creek (Kersey Creek of the map), about 5 miles S. of the turnpike; in another instance at a point nearly opposite, on the W. side of the same stream; and in a third at Kyler's, situated near the head of Little Toby Creek. Some of the results included in the sections were procured near the head of Brandy Camp Creek, at Mr Thompson's; and on Limestone Run, which enters Little Toby 4 miles below Jesse Kyler's.

On the road between Centreville and St Mary's, about 2 miles from the former place, along the bank of a small stream, tributary to Elk Creek, there is a deposit of bog-ore of several feet depth. On the hill-sides near by, a thin bed of slaty cannel-coal occurs: it has not been opened. On the hill-top N. of this, an impure variety of limestone strews the surface.

A large deposit of red bog-ore occurs on the land of Mr Thompson, near the head of Brandy Camp, adjacent to the conglomerate, and seems to be connected with filtration through the body either of this rock or of one of the ferruginous sandstones above it. Though no satisfactory exposures of Seral conglomerate were here seen near the level of the ore, the stratum was detected in the bed of the stream, at a somewhat lower level, 1 mile lower down the Brandy Camp, and 20 rods beyond was seen a bed of *limestone* in the edge of the creek, and over it about 40 feet of dark-coloured shale. This shale, in other localities, was discovered to abound in kidney ore, and the deposit in question might by some be referred to it, but I more incline to attribute it to the sources above adverted to. It covers in all an extent of perhaps 10 acres, and was proved to be in one place 7 feet deep, though its average depth is believed to be not so much.

The upper edge of the conglomerate seems here to be below the level of the stream; but 25 feet higher up are beds of shale, containing large masses of rather coarse nodular iron-ore, and at an elevation of about 75 feet there is a seam of coal, from 3 to 4 feet thick, the upper part of which is cannel coal. About 25 feet still higher in the series lies a bed of limestone, characterised by small univalve fossil-shells. Indications of a still higher seam of coal occur in the channel of the run above this limestone. Directly under the coal below the limestone is a layer of excellent fire-clay. The position of these beds in the series will be readily seen from the section to be presently given.

The lower limestone near the conglomerate was met with again between 5 and 6 miles to the S.S.E. on Limestone Run, which enters Little Toby about that distance S. of the turnpike, and heads 3 miles still farther S. The rock here is of a lighter colour, but it contains the same fossil shells and encrinites. This bed was found by one of our party 6 feet thick on an adjacent run, accompanied by a trace of coal directly beneath it, supported by a layer of fire-clay containing balls of iron ore. This is about its thickness on Limestone Run, where almost immediately below it lies the upper edge of a band of sandstone, just visible, with many imbedded impressions of fossil plants. This stratum was supposed to lie not far above the conglomerate. About 15 feet over the limestone is a shale abounding in iron ore, the lumps of which are numerous in the channel of the Run. It is of various qualities, but promises well as far as quantity is concerned.

Signs of coal occur here, evidently dislodged from some higher level, though the outcrop of but one bed has been opened and mined. Coal was obtained from it for lime-burning by Dr Earley and Mr Kyler. The hill ought to contain, we conceive, at least three seams of coal; but its position, it should be observed, is on the S. margin of the Coal-measures. The soil of the adjacent country is decidedly good, and we have shown that the region is far from being deficient in mineral treasures. The day must come, therefore, when it will sustain a considerable population. The hills are by no means high, rarely more than 300 feet. Pine timber is abundant, and our commoner hardwood trees attain a very large size. The settlers are still thinly scattered.

In collecting the results of the following sections, our practice was to open the outcrop of all the more important beds sufficiently to ascertain their exact thickness by measurement. While obtaining materials for this description, we were much assisted by Mr Jesse Kyler, from whom we derived much valuable information.

The comparison of the sections in column does not settle the identification of the various beds. The best guide hereafter will be the limestone with univalve fossils.

Column (fig. 374) near Parkhurst's (Horton's), E. side of Brandy Camp Creek:—

Olive shale; Coal, slaty, 2½ feet; Blue sandstone, 20 feet; Black slate, 2 feet; Coal, good, 2 feet 8 inches; Grey sandstone, 15 to 20 feet; Bluish-grey sandstone, 10 feet. Interval, supposed to contain a limestone; Olive shales, more than 5 feet; Dark sandstone, 7 feet; Coal, slaty, 1 foot; Black slate, 1 foot; Bluish shale, containing ore, 8 feet; Grey sandstone, more than 20 feet; Interval of a few feet, supposed to contain a limestone; Coal, good, 2½ feet; Fire-clay, 6 inches; Blue shale, abounding in kidney ore; Interval, 30 feet; Sandstone, 2 feet.

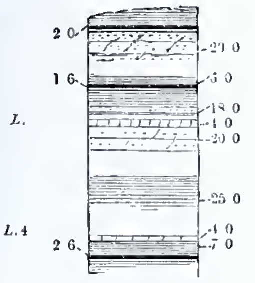


Fig. 372.—Brandy Camp (opposite Horton's).

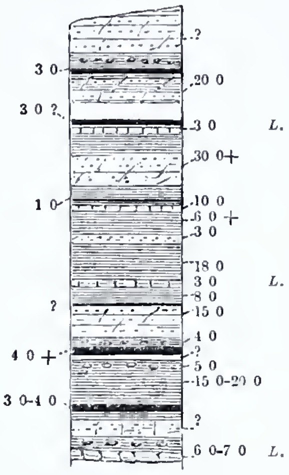


Fig. 373.—Little Toby Creek (Kyler's Coals).

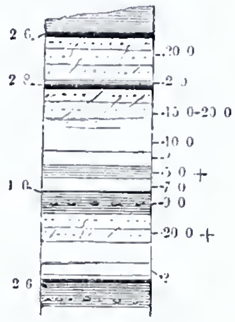


Fig. 374.—Brandy Camp, (Horton's.)

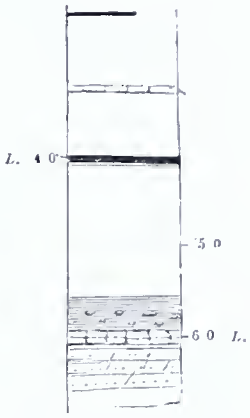


Fig. 375.—Limestone Run.

The abundance of iron ore in the bluish shale near the bottom of the section, and a comparison of the several beds with those found on Limestone Run already described, lead to the inference that the interval of 30 feet immediately below must contain the lower limestone of the section following.

Section of the strata in the hill on the W. side of Brandy Camp Creek (Fig. 372), opposite Parkhurst's (Horton's):—

Olive Shale. *Coal*, good, 2 feet; Fire-clay. Sandstone, 20 feet; Olive Shale, 6 feet. *Coal*, cannel, 1½ feet; Black Slate, 12 feet. Sandy Shale, 2 feet; Black Slate, 1 foot; Sandy Clay, 3 feet. *Limestone*, blue compact, 4 feet; Sandy Olive Shale, 20 feet. Black Shale, 2 feet (Coal probably thinned out); Blue Shale, 25 feet. *Limestone*, blue compact, 4 feet; Olive Shale, 5 feet; Black Slate, 2 feet. Coal, 2½ feet (lowest bed exposed upon the Creek).

Section of the strata at Kyler's, 1 mile S. of the turnpike, head of Little Toby Creek—(Fig. 373):—

Coarse Sandstone; Shale, containing ore. *Coal*, good, 3 feet; Sandy Shale, 20 feet. *Coal*, slaty, 3 feet. *Limestone*, 3 feet; Shale and Sandstone, 30 + feet. *Coal*, about 1 foot; Impure Limestone and Shale, 10 feet; Olive Shale, 6 + feet; Conglomeritic Sandstone, dark-coloured and somewhat calcareous, 3 feet; Blue sandy Shale, 18 feet; Impure Limestone, compact, 3 feet; Olive Shale, upper part, a compact whetstone, 8 feet. *Coal*, slaty, thin; Sandstone, thin-bedded blue and grey, 15 feet; Blue Shale, with nodules of sulphuret of iron, 4 feet. *Coal*, 4 + feet; Slate, &c. (?) feet; Brown Shale, containing iron ore, 5 feet; Black Slate, from 15 to 20 feet. *Coal*, of good quality, 3 to 4 feet; Fire-clay, sandy; Sandstone and shale, with kidney ore, 50 (?) feet. *Limestone*, 6 feet.

The two lower coal-beds of the above section have been opened at various points in the vicinity of Centreville (Kersey). The lowest has been mined by Dr Earley, by Mr Macready, and by Mr Howe. The mine of Mr Jacob Taylor, a mile S. of Centreville, is probably upon the same bed. Here the coal is said to exceed 6 feet in thickness, but could not be examined by us, the earth having fallen over the opening. At the village of Centreville, a coal is opened at water-level, measuring 3 feet 6 inches. Fifty or 60 feet higher in the series a coal 1 foot thick is found, and above it are indications of a slaty cannel-bed. The second bed ascending is opened by Mr Kyler and Mr Whaland on Little Toby Creek, and by Mr Keller: it is probably the same as the larger seam at Centreville.

We conceive the limestone at the base of the above vertical section to be identical with that found in the neighbourhood of St Mary's, where it overlies several beds of coal, as we shall hereafter show.

The lowest of the blue limestones of the section opposite Horton's being discovered nowhere else, and being somewhat sandy, we have supposed it might disappear by degenerating into a calcareous sandstone. The coal-seams vary considerably in thickness and quality, showing a transition from glance to slaty cannel-coal or bituminous slates. The second coal ascending, recorded in the sections at Horton's and at Kyler's, appears to have thinned away in the locality opposite Horton's. It may possibly have escaped notice in the stratum marked black shale, as slaty cannel-coal, of which it consists at Horton's, much resembles at its outcrop a black coal-slate. These coal-seams have been worked to a limited extent for consumption in the neighbourhood. The shales and sandstones, it will be observed, graduate into each other without regularity. The first bed of limestone ascending in the series, contains a small univalve shell, apparently a goniatite, which, being easily distinguishable from the fossils of the upper and lower limestones, may serve as a feature by which to recognise the stratum. No bed of iron ore was discovered so promising as that in the lower bed of shale, though less abundant exhibitions of ore are not unfrequent in other members of the series.

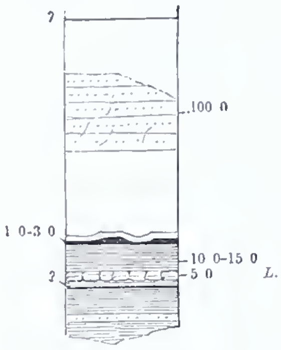


FIG. 376.—Hemlock Run.

The neighbourhood where the foregoing sections were obtained is about 8 miles from the Clarion River. The country around possesses a pretty good soil, and the surface is such as to admit of the construction of good roads.

Approaching the Brookville Turnpike, a section, represented in Fig. 376, was obtained upon the Little Hemlock Run, near where it is crossed by the Brookville and Toby Creek road, 9 miles E.N.E. of the former. The Third Axis is supposed to pass close by it upon the E. This fact, while it properly throws the section into the next basin, also serves to identify its limestone with one of the lower beds in the series. It dips N.W. 80°. Beneath it is a coal-smut, supported by 5 feet of black and blue shales, then sandstone.

Over the upper much-crushed coal-bed is a bed of fire-clay, which indicates the presence elsewhere of an upper member.

The sides of the ravine in which the little creek flows, seem to be composed wholly of hard sandstone, perhaps 100 feet thick, and then upon the face of the country around the coal-bed presents its outcrop in a terrace, as yet nowhere mined.

At the *Brookville and Curwinsville Turnpike* the Fourth Basin is of sufficient depth to retain a great depth of olive shales and black and variegated slates, which are exposed along the turnpike between Goodlander's Tavern and the opening upon a large coal at Fuller's Old Bank, 2 miles E. of Reynoldsville. On the W. side of the basin Coal-measures are found until we pass W. of Baum's Tavern, upon the turnpike crossing the high lands. Opposite the tavern a coal-bed 4 feet thick has been opened above a bed of limestone. Half a mile W. of Woodward Reynolds' a bed of coal has been exposed in the cuttings of the road; over it are many feet of green and grey shales, and under it a mass of slates and shales, and then a massive sandstone. Its terraced outcrop is well marked on the hill. A spring issues from it.

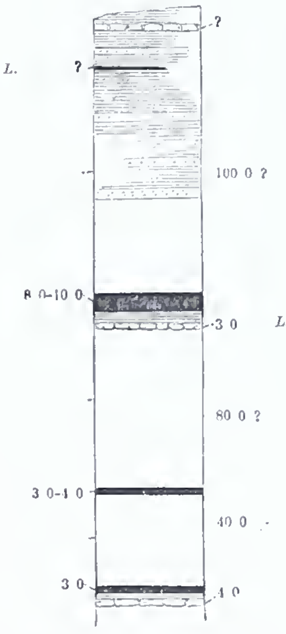


FIG. 377.—Reynoldsville, S. Branch of Sandy Lick Creek.

The accompanying column (Fig. 377) was constructed from data obtained in the vicinity of Reynoldsville and Woodward Reynolds' Tavern at the South Branch of Sandy Lick Creek.

The limestone indicated at the base of the Section appears in the bed of the South Branch, about a quarter of a mile below the Turnpike Bridge, and is partly carbonate of lime and partly carbonate of iron, coarse and blue. It seems to be 4 feet thick, and may be more. How much above it the coal-bed may lie which was formerly mined from the bed of the stream half a mile higher up, does not appear, but the distance cannot much exceed 10 feet. This coal-bed yields 3 feet of excellent coal where the running water has least eroded it. Both coal and limestone are almost perfectly horizontal, and no exposures occur in the precipitous hill-sides of the creek between the two strata. The same two beds, similarly ambiguous in relative position, and thus evincing close proximity, are to be seen upon a little run some miles E. of this locality, near Mr Standring's farmhouse. At this point one or two higher small coal-beds are found. Forty or fifty feet still higher in the series is a bed of coal, formerly wrought below the turnpike W. of Reynoldsville, and in the field back of Woodward Reynolds' house. It is said by those who opened it to be fully 3 feet thick. The next important stratum ascending is a large bed of coal. This seam, which is important because of both its size and purity, is wrought at various points in the vicinity of Reynoldsville. The nearest mine is that of Thomas Reynolds, where the bed measures 7 feet 8 inches from top to bottom. The upper 12 inches are rather soft. Two thin layers of slate divide the bed, one 2 feet from the top, the other 18 inches from the bottom. Only 5 feet of the coal are mined for use. S. of the town the bed is opened by Woodward Reynolds, J. Sheesley, Ludwick, and others. At Woodward Reynolds' it attains a thickness of from 10 to 11 feet, though the upper 4 feet are somewhat slaty. The remainder is mined. The coal is hard, lustrous, and remarkably pure; it finds a ready market throughout the surrounding country. It is important to remark that beneath the large coal at Woodward Reynolds' bank, and at Thomas Reynolds' old bank near the village, a stratum of limestone is met with; though in some places 3 feet thick, it is not always found. Woodward Reynolds used it to supply lime for building purposes.

At Reynoldsville the outcrop of the coal may be seen, 125 feet above the creek, circling round the hill. No higher coal-bed is seen above it there, though the more elevated points contain a small seam many feet over it. The large bed is betrayed by its smut, on the turnpike E. of Cather's Mill, on the land of Mr Fuller, by whom it has been mined. The small bed appears on the high ground above. On land formerly owned by Tilton Reynolds, now in possession of his heirs, the Big Coal is opened on the hill-side below the turnpike; at this point it is much higher than at Reynoldsville, and seems to be approaching its E. outcrop. No coal of like dimensions has been opened E. of this towards Luthersburg, and the question whether, after crossing the third axis, it enters high ground again, or whether it reappears under reduced dimensions, is not susceptible of solution until the several beds of coal and limestone are systematically proved and compared. The question of most preliminary importance touches the relationship which the limestones at Reynoldsville bear to that which we shall presently notice as found at Luthersburg. Much hesitation is felt in giving names to the several beds, but if we accept the most probable view, we shall regard the large coal as an unusual development of the Lower Freeport Coal—which, we know, fluctuates more than almost any other—and the limestone beneath it a purely local deposit. In this case the lower limestone will represent the ferriferous stratum.

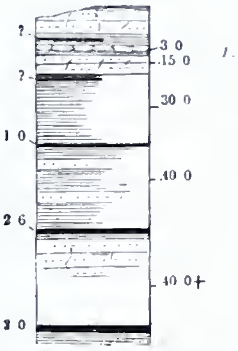


Fig. 378.—Luthersburg.

Passing into the Third Basin, we find in the neighbourhood of *Luthersburg* the strata exhibited in the Section (fig. 378). The principal openings are those of Irvin and A. Pentz. The former has developed two beds in the woods N.E. of the town. The upper measures 2 feet 6 inches, the lower from 2 feet 6 inches to 3 feet. The lower coal is mined by Pentz, near the Clearfield Turnpike, three-fourths of a mile E. of the town, where it is 2 feet 8 inches thick. Forty or fifty feet above it, on the turnpike, indications of the upper bed are seen resting on fire-clay. The same bed was penetrated by Mr Hover's well on the hill-side at Luthersburg; it was encountered 9 feet below the surface, and proved to be 2 feet 6 inches thick.

A coal-bed 1 foot thick was cut through by several wells on the higher ground at Luthersburg, at Long's, Dr Wilson's, &c.: it ranges through the town at the level of the roadway at Moore's Tavern. The existence of a fourth bed appears to be indicated by springs and black dirt on the hill just E. of the town. It has never been opened, but cannot be thick. Above this locality, on the Curwinsville Turnpike, limestone has been quarried to a small amount by Mr Irvin; it occupies only the high ground. It is grey, compact, sonorous, and, when weathered, yellowish or brownish, from the amount of iron which it sometimes contains. It was seen non-ferruginous at a place one and a half miles S. of the Turnpike at Luthersburg. Above the limestone is the black dirt of a coal-bed. The summit of the hill at the Curwinsville Turnpike, E. of Luthersburg, is a coarse micaceous sandstone, displaying impressions of Calamites. A coal-bed crops out on the road about a mile and a half E. of the town; it is probably the second coal, ascending, of the section. At Seyler's Foundry, one mile and a half N.W. of the village, a coal-seam corresponding to the lower bed is wrought.; it is 4 feet thick. At Reisinger's, 4 miles N.E., limestone is taken from the hill-tops, and burnt for lime.

CHAPTER XI.

FIFTH AND SIXTH BASINS IN POTTER, M^{c}KEAN, ELK, AND FOREST COUNTIES.

The lowest coal-bed is wrought at a spot 2 miles N. of the Smethport Road, 4 miles W. of Coudersport. It is opened on ground 40 or 50 feet lower than the highest surface of the hill. A shaft was sunk in grey sandstone to a depth of 30 feet to reach the coal of the drift, but it was not deep enough. At the outcrop the bed measured from 16 to 20 inches in thickness, and a drift was carried in upon it 200 or 300 yards. In the drift the coal expanded to a thickness of 3 feet 7 inches, and at the end of the workings it measured 3 feet 11 inches. It is subdivided by 2 inches of slate. The lower bench is a little slaty. The coal is pronounced very good by blacksmiths. The same bed makes its appearance upon the Olean Turnpike about 6 miles from Coudersport, and probably in the deepest part of the Fifth Basin. Blocks of conglomerate lie in confusion upon the surface of a steep slope 50 feet in height, above which are two regular terraces, each at least 60 feet in height. Here the coal may be opened.

The conglomerate can be traced along the sides of the valleys, and may be seen forming cliffs upon a hill-side within a mile of Coudersport, at the foot of which runs the Olean Road. Along the road are unequivocal upper Vergent green sandstones intermixed with red shales, which are doubtless to be referred to the Mansfield ore-stratum (described in treating of the valley of Wellsborough). Upon the red soil rest large blocks of conglomerate, slipped down from the cliffs above. The whole Seral-sandstone system must be here at least 100 feet in thickness. The base of the cliff rests upon concealed Vespertine grey sandstones, but the Ponent rocks are absent.

A small area of coal, perhaps overspread by the Seral conglomerate, is found in the centre of Sweden Township, S.W. of Stockholm. Iron Pyrites is abundant in the neighbourhood.

Coal is found to the Eastward in Pike Township, on Pine Creek, but it cannot belong to the true Seral Coal-measures.

In the extreme N.E. corner of Potter County, in Harrison Township, a variety of limestone has been found, and used for plastering; it is very impure. Passing along the road leading from Coudersport N. to Wellsville, alternations of red shale with olive and grey shale are quite conspicuous on the hill next N. of Glassmyres, to a thickness of perhaps 70 feet. Ascending the hill 1½ or 2 miles from Glassmyres, loose red matter is visible, succeeded by blocks of coarse thick-bedded rock; but after passing the summit, about 4 miles distant, the soil is again tinged deep red. Descending the long hill to Election Schoolhouse, a similar thick grey sandstone to that seen above is strewn in fragments on the surface. In the depression at the Schoolhouse the soil is red, but on the ascent N. of it its aspect changes, and a grey sandstone is strewn over the surface. On the top of the hill, 2 miles from Ellisburg, the soil is red and slightly gravelly; but a little beyond this point, brown, purplish, and green sandstones appear, and on the bank of the stream below, an exposure of some 20 feet thickness of mottled greenish sandy shales and shaly sandstones appears, having all the aspect of Ponent rocks. The whole thickness indicated above the quarry, where more of the greenish shale is ploughed up, must be at least 40 feet, and it is perhaps much more.

The same rocks are evidently exposed on the road in flags about half a mile S. of Ellisburg. If this is the case, the Ponent strata, to which these are referable, must be from 80 to 100 feet in thickness.

Northward of Ellisburg, occasional exposures of undoubted red shale soil and green flaggy rock appear; this occurs along the level as much as 50 or 80 feet above the stream, and again shows itself, mingled with green flaggy rock, on the high ground near the hill-tops, 2 miles from the State line. The exposures continue half a mile or more, after which green flaggy sandstone appears on the point of the hill, descending toward the State line. Between this point and Beansville, 1½ miles N. of the line, there are no exposures, though red shale is said to exist on the hill-top, half a mile S. of the latter place. At Beansville there are many blocks of white argillaceous sandstone, containing impressions of Scolithus, Encrini, &c., in the loose material.

The following strata are exposed in a descending order, in a hill 3 miles S. of Wellsville, New York—(See Fig. 379):—

Grey and brownish thick-bedded sandstone, 30 feet; Grey flaggy and brownish sandstone, 20 feet; Brownish sandstone with Cypricardia, 10 (?) feet; Grey flaggy sandstone, 20 feet; Red shale, 10 (?) feet; Green micaceous flaggy sandstone, 25 feet; Green micaceous flaggy sandstone, more thickly bedded, 25 feet; Green micaceous flaggy sandstone, brown, with coarse pebbly layers, 20 feet; Flaggy sandstone, and green and greenish shales, 20 feet; Strata concealed by blocks of grey sandstone, &c., with Cypricardia and other fossils, 50 feet.

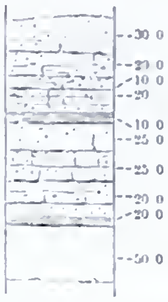


FIG. 379.—Cliff Hill, 3 miles S. of Wellsville, New York.—1 *inch* = 200 *feet*.

The very top of the hill in which the preceding section was made is occupied by grey and brownish rather argillaceous thick-bedded sandstones, some layers containing small pebbles. Below this are the flaggy rocks, underlaid by brown argillaceous beds, containing a profusion of Inoceramus, &c. This is a good locality for casts of these fossils. The shales appeared to have a thickness of about 10 feet. Beneath these occurs a grey flaggy sandstone, and then the earth is full of red shale, abundant and pure, just above the top of the ledge which forms the cliff, as seen from the road. Although this rock was not seen actually bedded, there can be little doubt that it occupies the position indicated beneath the fossiliferous layer.

The rock next below is the peculiar thin-bedded, platy, micaceous green sandstone, occurring so usually as an alternation with the red shale of the Ponent series; it is destitute of fossils. This graduates below into a more thickly-bedded but still flaggy rock of a soft, tough, rather conglomeritic texture, weathering to a peculiar buff-grey, such as has been noted in the vicinity of the red shale at points further S.

Below this is a similar rock, more brown when weathered, and brownish red within; in this are numerous pebbly layers, and fossil impressions are sparsely scattered throughout the mass. It passes below into a more thin flaggy and greenish sandstone, and green argillaceous shales.

The rest of the slope is concealed by the debris of the above sandstones, in which fossils are now and then seen.

As this hill is higher than those about Wellsville, it would seem that they are capped by the same rocks.

The Sixth Basin enters the State of New York, along the N. border of Potter County, and certainly contains no coal where it is traversed by the Coudersport and Olean Turnpike. Fragments of the Seral conglomerate are seen in great abundance in the neighbourhood of Ceres, upon the Oswaya Creek. Still farther N. we have yet lower strata: thus, in a quarry half a mile S. of Olean, we find well exposed a thickness of 20 feet of the Chemung or Vergent rocks, a few thin layers of which are very fossiliferous. Some of the partings between the sandstone flags consist of red shale, though the greater number of these are olive slate.

The quarry is at an elevation of at least 100 feet above the Alleghany River.

About 2½ miles S. from Olean, the hills embrace the following strata:—

1. Vergent Rocks of the usual Chemung type, at an elevation above the Alleghany River, at Olean, of about 350 feet.

2. Ponent Red Shale, visible on the side of a road leading up the hill from a steam sawmill, at an elevation above the river of 400 feet. Below this point at which the red shale seems to be in place, the ground is stained more or less distinctly for 50 feet with the red matter of the Ponent rocks, and displays red-shale fragments; but whether this series is in place for this thickness, is questionable.

3. Immediately above the red shale, at the Spring, appear beds of Vespertine grey sandstone, more or less replete with two organic forms. This group extends to the summits of the highest hills here, at an elevation above the Ponent of perhaps 100 feet. This Vespertine series consists of the evenly-bedded greenish-grey sandstone layers, weathering greyish white; they are from 1 to 12 inches thick, separated by partings of olive shale, which itself occurs in beds of some thickness. About half-way up in the mass, or 50 feet above the red shale, a quarry shows the sandstone in solid bands of from 6 to 12 inches in thickness. The uppermost layers on the summit of the hill are thin, and some of them contain small oval flakes, and pebbles of olive shale, seemingly derived from the Vergent rocks; also some vegetable remains, apparently stems of ferns. The other two organic forms spoken of as occurring in the rock are the bifurcating perpendicular stem-like fossil, seen in the hills near Warren, and the species of Scolithus likewise found in the same neighbourhood. These two transversely-disposed fossils appear to prevail most in the lower half of the first 50 feet of the mass.

The hill-tops throughout the N.E. extension of the Sixth Basin display huge scattered blocks of the Seral conglomerate, some of them of the size of a moderately-large dwelling-house. None of this conglomerate shows itself in place here; but from the magnitude of the blocks, it is plain that the original stratum lay very nearly at the level, and in the places occupied by these masses. It is said that the rock is not actually in place nearer than 5 or 6 miles S. from Olean. In lithological character, too, the conglomerate is somewhat peculiar, the pebbles being long and flat, and arranged very regularly several inches asunder, and generally parallel.

A well-defined N. and S. valley of denudation (one of the series of channels along the Northern tier of Pennsylvania, from Susquehanna County westward), is that along which, in opposite directions, flow the Driftwood Branch of the Sinnemahoning Creek, and that stream which unites the Alleghany River at Conoe Place, or Port Alleghany.

A similar long straight valley, parallel with the former, contains the waters of North and Potato creeks. Along these our chief observations were made.

Throughout nearly their whole extent, the Vergent and Ponent rocks occupy the bed of the valley, the high lands on each side being capped at the fourth axis by the Vespertine, at the edges of the fifth basin by Seral conglomerate (as also at the arch of the fifth axis), and by lower Coal-measures in the centre of the Fifth and Sixth basins.

Now almost all the bottom-washes of these valleys are full of an adulterated bog-ore, apparently the result of ferriferous water from the red bands of shale and sandstone, belonging, perhaps, to the Ponent Series, or to the thin remnant of the Umbral. The rock itself, in the road-ditches, &c., seems full of ferruginous moisture. No ore stratum, however, has been discovered. The best exposures of the rock are on the road from Smethport to Coudersport, about 4 miles E. of Smethport. Here the bands of rock seem to have a thickness little short of 100 feet. It forms a soil derived from the green Ponent sandstones. Occasional specimens of red sandstone appear. Many pieces are red outside, and encrusted on one or both sides with iron ore, while within they are grey and yellow, and filled with what might be taken for fossil cavities, but prove, when examined, to be but nodular cavities filled with yellow soil, and due to the abundance of ferruginous matter with which the rock is impregnated. The whole character of the band is ferruginous. There is little doubt that it has a relationship with the Marshfield ore-seam. It appears again on the Olean and Smethport roads, a few miles from Smethport; and 4 miles from Smethport, on this road, the band forms a bold escarpment 60 feet in height, the bottom of which is from 60 to 80 feet above the Creek. Again it appears on the Merain Creek, up which passes the turnpike to Bellfonte *viâ* Ridgeway. The red soil is here covered in patches with white sandstone, the Seral conglomerate from the adjacent heights. Again it is seen along the base of the Tunamaguont slopes, and with the same characteristics of rich chocolate-coloured soil and bold-terraced hill-sides.

In the upper part of this band of red rocks (the exact position could not be ascertained—probably at its extreme upper limit) is found, at Judge Otto's, a seam of good bright coal a few inches thick; and at a place upon Potato Creek, several miles above Smethport, in a little ravine on the W. side.

Limestone.—Not many feet above this, and about 200 feet below the conglomerate, are found in numerous places evidences of a persistent band of limestone. It occurs, for instance, on the hill-side, near the road from Potato Creek to Tunamaguont Settlement, and about 6 miles N. of Smethport, where a copious spring issues, charged with lime, which covers the stones and grass with a calcareous tufa. Similar springs issue upon the Warren Road, 6 miles W. of Smethport. On Bunker Hill, on the Bellfonte Turnpike, a specimen of fossiliferous limestone was found occupying this position in the series, under an exposure of very hard whitish Vespertine sandstone, dipping 7° S.S.E.

The bed itself was discovered beneath a cliff of similar hard whitish sandstone, 30 feet high, upon the run which enters Potato Creek from the Westward, 10 miles S. of Smethport. This limestone is 4 feet thick, exceedingly fossiliferous, very hard, and very sandy, being in reality a sandstone filled with fossil shells. It will sometimes make a sufficiently good lime for agricultural purposes. It seems to have been deposited over a wide area, as we discovered it upon Bennett's Branch to the S.; while there can be no good reason to doubt that the same band makes its appearance upon the Tioga River and Pine Creek, and even on Towanda Creek to the E. It has been recognised also upon the Tunamaguont Creek to the N.W.

The Vespertine sandstone series, in the base of which this calcareous stratum occurs, is upon the Driftwood, at the third axis, about 400 feet in thickness ; but, dwindling to the N., is little more than 150 or 200 feet in thickness at the New York line. At the same time it loses its distinctive lithological character, and, assimilating to that of the Vergent series (the Ponent being thin), the two often fuse, as it were, into one mass.

Fossils common to the Vergent series occur upon Bunker Hill, in the neighbourhood of the limestone above described, in exposures of green sandstones continuous with the Vespertine rocks. The lower strata of this series are in some places fit for building purposes. A quarry of fine slab-stones has been opened near Coudersport ; grindstone slabs of excellent quality are obtained near Smethport, in the lower Vespertine strata.

The Umbral red-shale formation has nowhere been fully opened, but everywhere gives evidence of its existence as a very thin stratum of variegated shale, accompanied by its well-known iron-ore. The places where bog-ore is found issuing from under the conglomerate are too numerous to mention. A few of the most important are at the Red Mill, near Instantur, in the Fifth Basin, and along the N. dips upon the ridge between Smethport and the Warren Road ; also on the Potato Creek and Tunamaguont Road, and 5 miles S. of Lafayette. Six miles N. of Smethport the ore itself was obtained. Here a vast bog covers the slope of the hill-side, while a copious spring issues from under the conglomerate, and within 50 feet of the top of the ridge.

Multitudes of these ferruginous bogs occur at the same elevation for miles W. towards Tunamaguont Creek. The ore was found by an unskilful digging continued for a month. It was an ore with a white core of a very fine texture. This place should certainly be opened thoroughly, as it is upon the N. limit of the ore, which here seems to give evidence of being of considerable value. It is on the stream coming in from the W. above Judge Otto's residence.

The Seral conglomerate is here sometimes a fine-grained conglomeritic sandstone, containing elongated pebbles, sometimes merely a flinty yellow sandstone ; but in the neighbourhood of the Smethport and Ridgeway Turnpike it is almost wholly a white massive sandstone, with conglomeritic layers at wide intervals. Upon the Tunamaguont Creek, on the contrary, one may remark pebbles imbedded in it, as upon Burnett's Branch, as large as an ostrich's egg. Such localities are remarkable, and the relations they bear to each other and to the rest of the area of the formation are worthy of study.

The fifth great anticlinal crosses the State line at the Genesee River, and ranges S.W. to Potato Creek, which it crosses S. of Smethport, N.N.W. dips being found in the neighbourhood of that town. Its course is thence up the valley of Marvin Creek to its head-waters. Passing through the water-shed between Marvin Creek and the waters of Toby Creek, or the West Branch of Clarion, it is lost in the wilderness country to the W. and N.W. of Montmorency, though its range S. carries it S.E. of Blood's Settlement (Marien) to the Clarion River. All the strata upon the N.W. side of this line are therefore thrown into the Sixth Basin, while those to the S.E. appertain to the Fifth.

The first appearance of Coal-measures in the Fifth Basin within the borders of M^cKean County is on the high land between Potato Creek and Alleghany River. It has been proved upon the lands of Mr Backus, within an area circumscribed by conglomerate, but what its extent is we have not been able to learn. Whatever is there found must evidently occupy a position low in the series.

At Smethport, Red shale occupies a large space on the hill-sides, at or near the tops of which conglomerate crops out. On the surface, about 2 miles W. from the town, are thickly-strewn blocks of this rock, many of them of great size, consisting of coarse and pebbly sandstone and Nut and Pea conglomerate. These are, no doubt, derived from the adjoining hill : it is probably 200 feet above the road-level itself, and much more above the level of the town. Associated with the Red-shale fragments is green shaly sandstone, and some of the dark ragged and pebbly rock. The Ponent Series (if it is correctly identified) in this vicinity cannot be less than from 150 to 200 feet thick.

The identity of the Red shales and sandstones with the Ponent series is a question of the more importance because this series, traceable over an extensive area, supports in parts of M^cKean County, as in more Western districts, a small coal-seam, which outcrops along a well-defined terrace, and even intimates its presence by a smut upon the Olean Road, 12 miles from Coudersport.

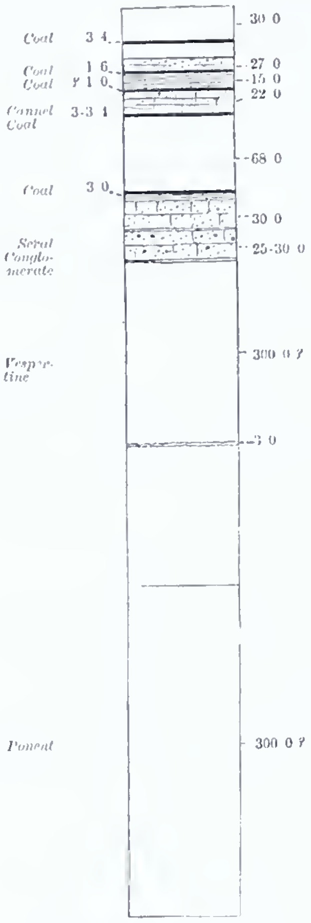


Fig. 380.—S. of Smethport.
1 *inch* = 200 *feet*.

Upon the upper waters of Potato Creek we are fairly in the Coal-measures.

The following section (Fig. 380) and notes of the stratification about 2 miles S. of Smethport have been in part furnished us: we cannot vouch for their accuracy.

Coal, dull and bright alternately, 3 feet 4 inches; Sandstone, &c., 27 feet,; *Coal*, 1 foot 6 inches; Slate, 15 feet; *Coal, in boring*, 1 (?) foot; Argillaceous sandstone, 22 feet; *Cannel Coal* (in boring 5 feet), 3 feet to 3 feet 4 inches; Interval, 68 feet; *Coal*, 3 feet; Sandstone and slate, 30 feet; Conglomeritic white sandstone, 25 feet to 30 feet; Vespertine strata, including 3 feet of limestone.

The upper coal was proved by a shaft sunk through shale 9 feet; it contained no layers of slate. The roof is a dark slate, 6 inches thick, and over this are 18 inches of argillaceous iron-ore in flat balls and plates. Beneath the coal are 3 feet of fire-clay.

The next coal, proved by a drift 42 feet long, is 18 inches thick, and contains one foot of good coal; the rest is slaty. This coal, bored into twelve rods from the drift, appeared to be 3 feet 4 inches thick.

The Fourth Coal, or that next in importance, was found by boring near the drift above mentioned, and proved 5 feet in thickness; but in a drift half a mile distant, where the coal had a covering of 18 feet, a seam, thought to be the same, measures but 3 feet 4 inches. The lower 3 feet of this bed is cannel coal; the upper 15 inches is soft coal, probably of the cannel variety. The lowest coal under a cover of 10 feet shows a thickness in a shaft of about 3 feet.

A Section of the hills upon the E. side of the creek, 3 miles from Norwich, is exhibited in the annexed woodcut (Fig. 381). The lowest bed was opened under a small cover and proved there to be little more than 3 feet thick: over it is seen the debris of a heavy sandstone. The coal itself is tolerably good, but intermixed with slate and slaty coal. It is better than a bed occupying a similar position near Coudersport, but not so good as farther W. The upper beds are marked by springs, bogs, and benches. In the springs, slate and some little coal have been found. The dip is S.S.W. apparently over 5°, and the outcrop of the beds seems to be the N. margin of the basin. S.E. of Norwich, between it and the Salt-works,* coal has been found upon the lands of the Monroe Coal and Iron Company. Mr Sheafer reports to have opened four small beds of from 1 to 2 feet thickness, and a larger bed, the fourth ascending, measuring 5 feet. A seam of cannel coal, 2 feet 10 inches thick, is said to be found in the same district.

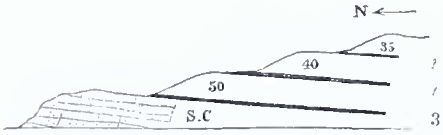


Fig. 381.—Potato Creek, 3 miles from Norwich.

Crossing Potato Creek to the high lands W. of it, still in the Fifth Basin, we come upon the coal-beds of the Bunker-Hill measures. The N. margin of the outcrop ranging from the Potato Creek somewhere near Norwich, the Smethport Turnpike crosses not far N. of Bunker Hill or Clermont Settlement; it then converges towards the fifth axis at the head-waters of Marvin Creek. Whether the Coal-measures lap over the fifth anticlinal between Marvin and Toby creeks is a point not yet determined; but should they do so, it can only be for a short range, inasmuch as they are again cut out by the deep valley of Toby Creek and its branches. The high ground between Toby, or the West Branch, and the East Branch of the Clarion, embraces coal strata S. to Johnsonsburg, which occupy nearly the centre of the Fifth Basin. S.E. of the East Branch of the Clarion, we have reason to believe coal may be found upon the more elevated tracts, as far as where it is denuded from the summit of the fourth anticlinal axis. W. of Toby Creek Coal-measures underlie the forest country at its head-waters, except where cut out by the deepening valleys of those streams. They appear even to cross the fifth anticlinal, and occupy the high rolling table-land in the Sixth Basin S. of the North Branch of Kenzua, and among the other waters of that stream. Between Marvin Creek and the N. Fork of Kenzua they embrace Howard Hill, and are prolonged N.E. to within 7 miles of Smethport. We shall hereafter show the distribution of the coal strata N. of the Kenzua.

---

* On the Portage Branch of the Sinnemahoning, 12 miles S. of the Alleghany River, boring commenced on Vergent rocks; augur broke at 350 feet depth; constant yield of a small quantity of brine. It was abandoned in 1852.

Returning now to the Bunker-Hill neighbourhood, we find the coal-beds opened by Mr Beckwith, as represented by the vertical column (Fig. 382). The limestone at the top of the section is found on a piece of land one mile S. of Mr Renshaw's, and is evidently a bed in ruins. Many pieces lie in the ground, and one was obtained several feet thick. This last reposed in a bed of fire-clay, and that upon blue compact shale. In the hill S. of this the soil on the outcrop of this limestone stratum was thought to appear. The limestone is a very good fine-grained blue carbonate of lime.

The upper coal is opened in Mr Beckwith's field, on the hill W. of the turnpike, and is said to have yielded excellent coal, varying from 1 foot 6 inches to 3 feet in thickness. The lower coal has been opened in two places. In one of these there were two equal bands of 2 feet each, with 4 inches of slate between. In the other, a few rods distant, the bed was 3 feet thick to the slate below, which had not been broken to see if still another band lay below it. Over the coal, in a stratum of slate, are heavy balls of bright sulphuret of iron. Near the openings is a large bog of ore soil which has been deposited from water welling out, most probably, from a stratum of blue carbonate of iron.

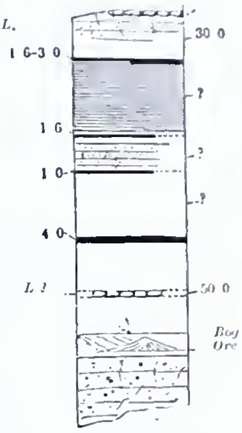


FIG. 382.—Instantur.

Several miles S. of Bunker Hill, near the turnpike, a heavy bed of bituminous slate has recently been opened. Although currently reported to be cannel coal, it has far more the character—if we may judge from specimens—of a highly-carbonised slate, or slaty cannel. We are unable to announce its precise thickness, but it is stated to be fully 14 feet.

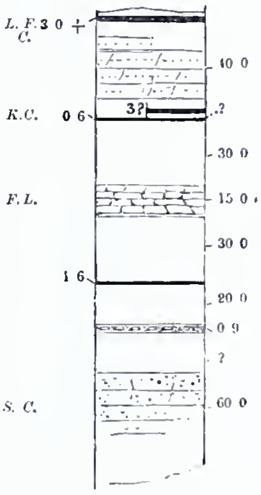


FIG. 383.—Judge Wilcox's.

Eight miles S.W. of the last locality a section was obtained on lands under charge of Judge Wilcox (see Fig. 383). The upper coal was opened years ago, by Mr Wescott, $1\frac{1}{2}$ miles S.W. of Judge Wilcox's house. The bed was not under good cover, yet it displayed 3 feet of excellent coal. The next bed below has never yielded more than 6 inches of coal near the line of section, but is thought to represent a much larger bed. Some miles farther S.W. upon the old Jefferson County line, Mr Sweet opened a bed in two bands 2 feet apart, yielding 3 feet 9 inches of coal. This may be upon the horizon of the upper seam in the section, but we are disposed to consider it lower. On the high ground E. of Johnston's Run, a tributary of the East Branch of the Clarion River, and near Mr Miller's house, half a mile S. of the turnpike, there is a quarry of limestone. It was discovered by a sinking spring. As exposed, the stratum is 15 feet thick, but how much thicker cannot be told. The rock is fossiliferous, of good quality, hard and brittle, and makes a strong grey lime. It is of great importance to this country, otherwise very destitute of lime; it can find a market in the State of New York, and has been sold, we learn, in Olean. It ranges through the middle of the basin, but as it does not appear to produce the peculiar loamy soil, the colour of which is so indicative of the presence of a bed of limestone, it has been impossible to trace the bed; a little careful research will develop its large outcrop wherever it exists. Intimations of the presence of a bed are given on the Warren Road, 5 or 6 miles W. of Montmorency, but whether of the same bed or not, we cannot say; indeed, the horizon of this great limestone stratum is as yet very obscure. Our observations in its neighbourhood led us to place it low in the series, as the equivalent of the ferriferous limestone; but the developments made upon the Kenzua and Marvin Creek waters, farther N., have failed to detect its presence, and those who have conducted local surveys there, regard it as very high, and perhaps even overlying the entire series in those parts. At some future day, when the stratification beneath it has been determined, a reliable key to its position will be furnished, and the bed will be opened elsewhere. The coal-bed next below the limestone was not opened in such a manner as to insure the development of its whole thickness. The iron-ore band beneath this may prove of importance. It was discovered on two brooks, lying in long flattened balls, weighing from 20 to 30, or even 50 pounds, and some of them having a maximum thickness of 9 inches. It is a blue carbonate, rather coarse in the grain, and if found in more than one such layer, will be worth working. The rock lying beneath this series is a massive white sandstone from 60 to 100 feet thick.

At the confluence of the East and West Branches of the Clarion, at Johnsonsburg, three beds of coal have been opened on Dickinson's land by Mr Jesse Kyler. The lowest of these, lying close to the conglomerate, is 2 feet 10 inches thick at one opening, but at others does not exceed 1 foot 6 inches. The second bed is 16 feet higher, and measures 1 foot. The third is perhaps 60 feet above the last, and proved to be 4 feet 10 inches in thickness. It occupies a high position in the hills, and covers but a limited area in this neighbourhood. They all dip gently S.E. The same beds of coal have been opened on Dickinson's lands, 1½ miles S.W. of Ridgeway. Here the top bed is only 6 inches thick; the others are 20 inches and 1 foot respectively. On Spring Creek, near the county-line of Forest, the same beds are ascertained to exist. Two miles E. of Montmorency, a coal-bed, said to be 5 feet thick, was opened years ago.

On the E. bank of the Clarion, below Johnsonsburg, a bed of splint coal, or a mixture of coal and slate, has been opened about 40 feet beneath the Seral conglomerate, and there are indications of others.

We shall presently see that the three coal-beds above mentioned occupy nearly the same relative position in the neighbourhood of St Mary's.

St Mary's.—On the lands of the Ridgeway farm and Coal Company, near St Mary's, coal has been opened at various points. On the low ground at Iron Run, in the village, the Seral conglomerate makes its appearance as a somewhat coarse-grained yellowish sandstone, with ferruginous streaks. Some of the beds are slightly conglomeritic. Upon this coarse sandstone reposes a pure white silicious sandstone, the freshly-broken surfaces of which present an appearance not unlike that of loaf-sugar. This rock may be seen on the brook which flows by the Theresa Street Mines.

The annexed vertical Section exhibits the stratification at St Mary's (see Fig. 384).

On Theresa Street, above the sandstone, three beds of coal have been opened; the lowest is 12 or 15 inches in thickness. In the slates immediately above this coal, balls of dull white or grey carbonate of iron have been found. The quality of the ore is excellent, but the openings have not been sufficiently extended to ascertain its quantity. Not more than 15 or 20 feet above this bed occurs another coal, measuring 18 inches, above which a thick stratum of ore has been proved. Oval flattened masses of blue carbonate of iron repose in close contact within a thickness of from 2 to 4 feet, and masses are found in the slates still higher. 30 or 40 feet higher, another 18-inch coal-bed is opened. None of these seams have been mined at the localities mentioned.

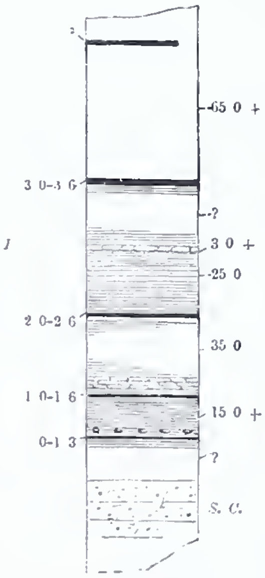


FIG. 384.—St Mary's (Fifth Basin).

On the Monastery lands W. and N.W. of the Catholic church, two of the coal-seams to which we have been adverting have been opened. The upper is 2 feet or 2 feet 6 inches thick, the lower from 12 to 16 inches.

On the higher grounds, in the S. and W. parts of the town, limestone is found at various places. It is a very hard dark-blue rock, and burns to a light-grey strong lime. The thickness of the stratum has never been tested, but it certainly exceeds 3 feet. The presence of this bed adds greatly to the value of these lands for agricultural purposes. We have before expressed our conviction that it is the same stratum which lies at the base of our section at Kyler's, on Little Toby Creek, and it may prove to be the S. prolongation of the great bed seen at Wilcox's. It appears on the Olean Road, near St Mary's, and is evidently beneath the bed of coal that has been mined E. and N.E. of the town.

The principal openings on the coal-bed over the limestone are those of Allis, Nist, Bucheit, Glot, and Anthony, in which its thickness varies from 3 feet to 3 feet 6 inches. The roof and floor of the coal are usually thin bands of bituminous slate. The same bed was cut in Corbe's Well, and may readily be opened at various points on the hills. From 60 to 70 feet above this bed there are indications of a coal-seam, but it has never been fairly opened. It was seen at Nist's Spring, near his house, and not far from the road on Bucheit's land. The bed is apparently thin. The limestone stratigraphically under these beds is opened on Mr Shaeffer's farm, N.E. of St Mary's. The entire stratification in the vicinity of the town is gently N.W., towards the axis of the Fifth Basin. Coal displays itself on nearly every hill between St Mary's and Roselay. It has been opened at several points by Mr Hanhauser; but at Roselay the coal strata are thrown off from the back of the fourth anticlinal.

On Elk Creek, near Mr Garner's barn, in the village of St Mary's, there are indications of a small deposit of bog-ore.

Owing to the gentle undulating dip of the Seral conglomerate W. towards the Clarion, the coal strata do not appear to increase in thickness in that direction. To the same fact is attributable the absence of Coal-measures bordering the Centreville and Ridgeway Turnpike W. of the fourth axis.

On the Clarion River, 1 mile below the mouth of Little Toby Creek, and about 20 rods above that of Bear Creek (Beaver Creek on the map), there occurs on the E. side of the river a fine deposit of bog-ore. The Seral rocks, descending, here occupy the middle third of the hill, and form a stratum at least 100 feet in thickness. Five or six springs, in a space of about 30 roods, issue along the lower edge of this rock, each of them depositing the pulpy red oxide of iron along the slope leading down to the river. Probably 20 acres are covered with the deposit, the average depth of which may be given at 7 feet. The coarse conglomeritic sandstone above is exposed, but the more flaggy Umbral beds show themselves at the base of the hills, where the contact of the two formations is clearly marked by an abrupt change of slope at the level of the springs. Huge blocks or masses of the overlying rock have detached themselves from the body of the stratum along the face of the hills. Though partly conglomeritic, the largest pebbles rarely exceed a hazel nut in size. The hills rise about 100 feet higher than the upper edge of the conglomerate, and about half-way in this interval, or some 50 feet below the summit, occurs an indentation or bench which may possibly imply the existence of a seam of coal.

On the hill, ascending by the turnpike E. from Ridgeway, the fine white clay, mixed with minute fragments of red shale and fine-grained iron-ore of the Umbral formation, may be seen. It is from this clay that the springs issue which, up and down the Clarion, deposit the bog-ore we have been describing.

CHAPTER XII.

THE SIXTH BASIN SOUTH-WESTWARD.

THE general character of the Sixth Basin, in the central and W. parts of M^cKean County, is that of a wild rolling upland, drained by the constantly-deepening channels of the tributaries of the Alleghany River flowing N. and W. Until within a very recent period it has received but little attention, and our explorations within its borders were governed by the few widely-separated openings upon coal, and the sometimes doubtful identification of the coarser rocks which mark specific horizons of deposit. Within the past two years the extensive surface-explorations of Mr A. F. Dalson upon the lands of the M^cKean and Elk Improvement Company, and of Professor Owen, Professor Hall, and others, upon the Tunamaguont waters, have guided us to a more accurate knowledge of the stratification. The full development of all the beds of coal, with the included bands of shale, slate, sandstone, &c., was long ago felt to be a desideratum, and to this we have now in some degree attained.

The following section, furnished by Mr Dalson, embraces the series of coals and intervening measures found to occupy the higher hills at the head-waters of the South Branch of Kenzua Creek in ascending order:—

Strata undeveloped, including three small beds of coal, occupying a high knoll on County Warrant, No. 3131, 60 feet.

1. *Coal*, slaty, 2 to 4 (?) feet, usually called the "Splint Bed;" sandstones, and black and green shales; ore in lower part, 38 feet; sandstone and shale, iron ore at bottom, 15 feet; sandstone, fine-grained and ferruginous shale, 13 feet; nodular iron-ore in compact bed, 5 feet, known as the "Rockwell Ore" stratum. This we regard as the

base of the Umbral formation. Below this succeed brown and olive sandstones, and a band of pebbly sandstone or conglomerate, beneath which is found a stratum of bluish-grey fossiliferous limestone, 5 feet thick, occupying a low position in the hills along the deeply-cut ravines. We have shown in the previous chapter that this is a persistent band of limestone, being found in various parts of McKean County, and S.E. upon Bennett's Branch.

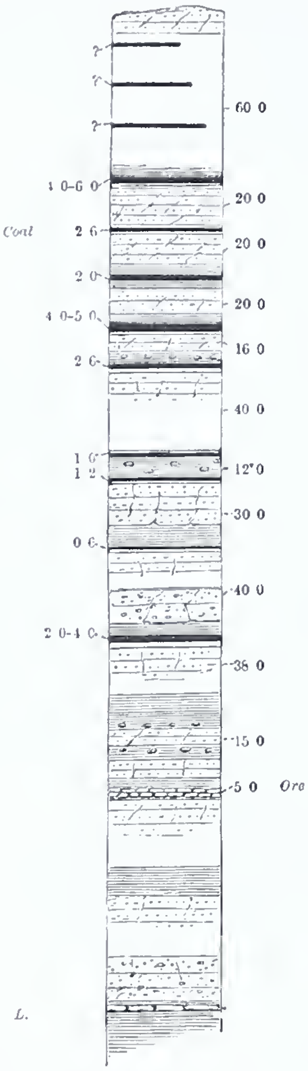


Fig. 385.—Head-waters, South Branch Kenzua Creek.

2. *Coal*, 6 inches; shale and iron ore beneath; compact white and pebbly sandstone (Seral conglomerate), 40 feet.

3. *Coal*, 1 foot 2 inches; compact grey sandstone, 20 feet; ferruginous shale and fire-clay, 10 feet.

4. *Coal*, 1 foot; slate and shale ore-balls, 12 feet.

5. *Coal*, 2 feet 6 inches; fire-clay, fine and coarse sandstone (Tionesta sandstone), usually denominated "the Pink sandstone," 40 feet.

6. *Coal*, 4 to 5 feet, including slate and clay partings, 6 to 6 feet 6 inches. This is regarded as the equivalent ofthe Bond Seam of Lafayette.

7. *Coal*, bituminous, 2 feet; slate-sandstone and slate, 20 feet.

8. *Coal*, cannel, of good quality, 2 feet 6 inches, including a layer of bright bituminous coal at the bottom; flaggy sandstone and shales, 20 feet.

9. *Coal*, of good quality, 6 feet; this is probably the equivalent of the uppermost bed proved N.E. of Howard Hill, on Warrant No. 2665, where it measures 4 feet; also of the L. Davis Bed, 5 feet thick, at Lafayette; fire-clay and flaggy sandstone, 20 feet.

The full series of strata embraced in the above section are found only on the higher points at the heads of the streams in the central parts of the basin N.W. of the fifth anticlinal. The usual covering of the district we are describing, S. of the North Branch of the Kenzua, is the second great Coal-measure rock, the Tionesta sandstone, which has served to protect the coal strata lying beneath it, and above the Seral conglomerate, as shown in the diagram (Fig. 385). The precise areas occupied by the upper coals can only be determined by careful research and the use of instruments.

The so-called "Splint Seam" belongs to a group of coal strata which, although appertaining to the true Seral coal-formation, were long ago recognised as lying beneath the main body of the Seral conglomerate. In a future chapter this group will be shown to embrace one, and sometimes two, important beds of coal. Though the bed is frequently a mixture of coal and slate, as its name implies, it is generally estimated among the workable coals of the region, and, as such, will be accepted as the horizon for defining the coal areas N. of the North Branch of Kenzua Creek.

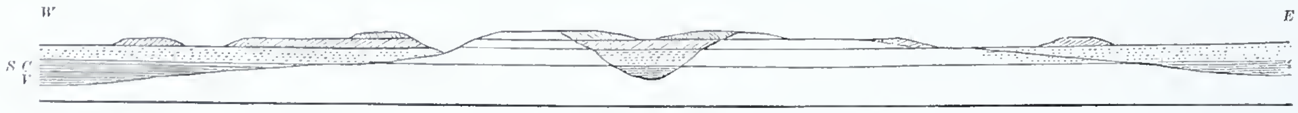


Fig. 386.—Section exhibiting the two Sandstones overlying the Seral Conglomerate W. of Smethport, with the Coal between.

N.W. of Smethport a small patch of Coal-measures is found occupying the high ground S. of Cole Creek. This may be an insulated area, or is probably connected with a more extended field, the outcrop of which is met on the road between Smethport and Lafayette, about 4½ miles W. of the former place. From this point the S. outcrop observes an irregular course, determined by the conformation of the surface, bordering the valley of the North Branch of Kenzua Creek, from which it gradually recedes, passing S. of Lafayette and N.W. towards the Alleghany River, at the head-waters of Sugar Creek. Passing some miles W. of Marsh's Corners, among the head-waters of the West Branch of the Tunamaguont the outcrop deflects E., and crosses the Tunamaguont Creek to the place of departure. We have thus an area of about 15 miles in length and 5 in average breadth occupied by coal.

Estimating in a rough way the entire thickness of the coal strata as developed from the conglomerate border of the coal area towards the central parts of the basin—as, for instance, from Davis's Sawmill S.W. of Lafayette towards the latter place—we think there are not less than 200 feet of rock, including several beds of coal. The Seral conglomerate, as exposed near the sawmill, is a coarse white sandstone ; some layers are full of small pebbles of the size of peas and millet-seed.

W. of the Tunamaguont, and N. and N.W. of the general coal area which we have indicated, several small patches of coal are found separated from each other by deep watercourses. Such an one is that embraced by the two main branches of Sugar Creek. This tract occupies a flat summit about 2 miles in length from E. to W., and three-fourths of a mile wide at its W. extremity. The position of the only bed of coal that has been developed upon it is more than 30 feet above the upper edge of the Seral conglomerate or sandstone, from which it is divided by that thickness of coarse brown shales. The shales probably embrace one or two small beds of coal. The coal itself is about 15 inches thick, and has a dull aspect and slaty impurities. It is immediately overlaid by about 12 feet of dark-brown shale, in which are scattered a few small nodules of argillaceous iron-ore. The more elevated points of this district contain the lower part of the Tionesta sandstone, which rests immediately upon the brown shale, and is of a grey or yellowish colour, and sometimes much blotched and streaked with peroxide of iron (see Fig. 387) ; of which it is to be observed, in common with the four following sections, that it represents the only coal-bed known to exist between the Tionesta sandstone and the Seral conglomerate at the date of our earlier surveys. Subsequent researches have furnished a key which may lead to the development of others. The higher hills on the N.E. of the main Kenzua Creek appear to be capped by this upper sandstone, though the distance between it and the bed at the base of the formation is so small that we seldom obtain exposures of anything between them.

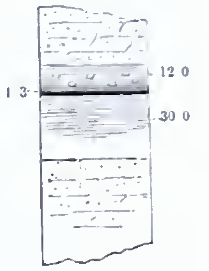


Fig. 387.—Tunamaguont.

Similar insulated areas of coal strata to that above mentioned occupy the higher grounds W. and S.W. of Littleton, upon the waters of the W. branch of the Tunamaguont Creek ; but the precise superficies covered by coal we have not ascertained. Most of these summits are capped by the Tionesta sandstone, though some of them are high enough to embrace one or two coal-beds lying above that rock. The Seral conglomerate ranges high in the hills, even beyond the State line into New York ; and the coal beneath it may be found at points not within the limits of our description.

The deeper parts of the Sixth Basin, within the area previously designated N. of the North Branch of Kenzua Creek, embraces the same series of Coal-measures which we have given in our description of the country S. of that stream. The published Geological Sections of Messrs Owen and Needham represent the same beds of coal, though under somewhat variable conditions as regards the thickness and nature of the intervening rocks, and of the individual coal-beds themselves. One or two coal-beds are enumerated by them as having a probable existence, for which we find no place in our section, nor have the seams of black shaly ore denominated " black-band " by those gentlemen been found to have a traceable persistency. The most important of these is reported to occupy a position in the shales between coals 3 and 4 of our enumeration. The coal-beds, Nos. 1, 5, 6, and 9, known as the Splint, Whitman, Newell, and Davis beds respectively, are all estimated as containing fully 5 feet of coal, except the first, which contains 4 feet.

Among the well-known coal-beds which were opened prior to the local surveys above alluded to, that of Mr Bond is worthy of mention. This bed contains from 4 feet 6 inches to 5 feet of coal, subdivided into 4 benches, with slate-partings of a few inches thickness. The second bench from the top is a cannel coal 18 inches in thickness. At Tildon's, near Lafayette, a similar bench of cannel coal is found included within a larger seam of the ordinary bituminous variety. The bituminous coal of this bed yielded, on analysis, 37½ per cent of volatile matter.

Coal has been opened on Mr Owen's land one mile S.E. from Mr Bond's, on Three-mile Run. Here two beds have been proved ; the upper by a drift carried in 80 or 90 feet, the lower by a shaft sunk about 20 feet to the bottom slate. The two openings are about 170 feet apart. The thickness of both beds is 3 feet ; the lower bed is good bright bituminous coal of clear fracture, without any bands of slate. It is underlaid by fire-clay, and overlaid by 10 inches of blue roof-slate, and over this 9 feet of slate, capped in the shaft by earth and rubbish. It is thought that the interval between the two seams does not amount to more than 10 feet of slate.

The coal opened in the drift is likewise 3 feet thick, the upper half cannel coal, and the lower bituminous.

At an interval estimated to be about 25 feet above the coal last mentioned, there is another which, at the outcrop, showed a thickness of 1 foot of cannel coal. It lies in a bench near an abrupt rise of sandstone. It is probable that the seam is thicker than its outcrop indicates.

There appears to be another bed of coal, about 40 feet beneath the lowermost of the three seams above mentioned. It has not been fully proved, but sufficiently so to show a bed of some promise. The fragmentary coal at the outcrop is pure, and of the bright bituminous kind.

W. of the Alleghany River we find a small patch of the Seral conglomerate near the heads of Pine Creek, about 3 miles S. of the New York State line, and nearly the same distance from the river. It is only a small insulated tract 1 or 2 miles in length, which has escaped denudation. It lies N. of a larger tract occupying a considerable area between the Alleghany River on the E. and Hemlock Run on the W., and extending 6 or 7 miles W. from the Alleghany River. It forms the river-hills on both sides of the mouth of Hemlock Run N. for about the same distance. E. of the head of Hemlock Run, and about 3 miles to the W. of Kenzua, is the only patch of coal found upon this fragment of the carboniferous table-land. It occupies only the highest summit, and its whole area does not probably amount to 1 square mile. The plane of the coal-seam is above the Seral conglomerate: its thickness averages at least 2 feet. Nowhere has it a covering of more than 50 feet of overlying shales and lower beds of the Tionesta sandstone.

N. of Warren there are three isolated knobs of the sandstone, upon which no traces of the coal-seam occur. One of these is immediately back of the town; the second, which is larger, is on the E. side of the Connewango, and below the mouth of Pine Creek; the third is in Pine Grove Township, 2 miles W. of the Connewango, and 3 miles S. of the New York line.

Advancing to the S.W. of the Kenzua, the region begins to assume the more definite character of a regular coal-basin, bounded on the S.E. by a broad expanse of the great Coal-conglomerate, brought up by the fifth anticlinal axis; and on the N.W., next the Alleghany River, by a high belt of the same rock.

This description applies to the whole drainage, or basin of the Tionesta, with its tributaries. All the central tracts of this trough, from the Kenzua S.W. to Racoon Creek, have their higher summits overspread by the second great sandstone, and therefore contain at least the one small coal-vein previously described, and perhaps others of the Tionesta series. A bed of coal has been opened in a few places, but from the thinness of the seam, and its position near the tops of the higher hills, it can never become of much economical importance.

The usual place of the coal-bed which our sections exhibit, is from 50 to 60 feet above the top of the Seral conglomerate, the intervening space being shale and slate; above the coal there generally rests a few feet of sandy shale, containing small scattered nodules of iron ore. Upon the shale lies the Tionesta sandstone, usually extending to the summits of the highest hills, the thickness of which rarely exceeds 60 feet.—(See Fig. 389.)

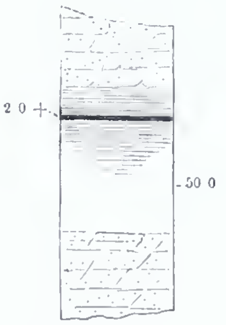


FIG. 388.—W. of Kenzua.

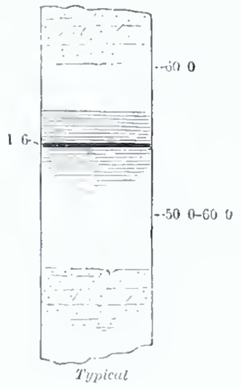


FIG. 389.—S.W. of Kenzua.

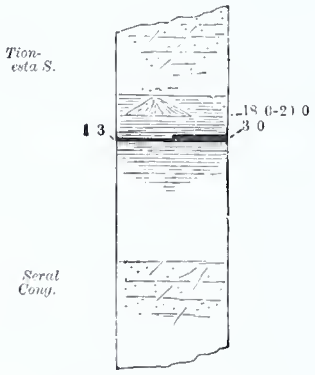


FIG. 390.—Little Alleghany River and French Creek.

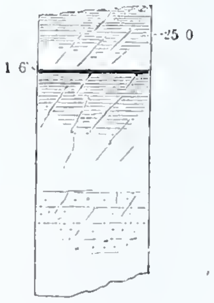


FIG. 391.—Near Franklin:

The usual thickness of the coal itself is about 18 inches. It has a dull aspect, and is rather slaty. It has been opened at its outcrop sufficiently to ascertain its thickness at Mr W. Johnson's, 9 miles E. of Warren, and 900 feet above the bed of the Alleghany; again in a hill about 11 miles S.E. from Warren, and bounding the Tionesta on the E., not far N. of the tavern on the Warren and Ridgeway Turnpike; again about 12 miles in a straight line due S. of Warren, where the coal is tolerably pure, but its thickness is only 15 inches.

Two miles S. of Kenzua there occurs, apparently in the Seral sandstone, which is 50 to 75 feet, and below the highest ground, a coal-bed 3½ feet thick, of which the upper 18 inches is cannel coal.

A bed of coal occurs in Quaker Hill on the W. side of the Alleghany River, about 8 miles above Warren; it is stated to be 18 inches in thickness, and of the ordinary bituminous variety, containing thin partings of slate. This coal lies in the Seral lower sandstone, or under the conglomerate.

About due S. from Warren 10 miles, and some 8 miles from the river, there is a bed of coal in apparently the same geological position.

The river-hills on the S.E. side of the Alleghany River display the following strata in the ascending order—(See Fig. 392):—

1. The upper portions of the Vergent or Chemung series some 300 feet or more. The fossil beds extend nearly to the upper limit of this group. No red or Ponent strata visible.
2. A group of generally thin-bedded sandstone, and olive-grey shale beds—some of the sandstone layers exhibiting a thickness of from 6 to 12 inches. These contain a bifurcating stem-like fossil perpendicular to the bedding, possibly a Coralline or a plant (?), and also a true Scolithus of the size of a thin quill, with a knob at the surface of the layer.
3. A massive quartzose conglomerate, with pebbles for the most part ovoid and smooth, and of the size of beans and small nuts. This bed is not more than about 10 feet thick.
4. Shales and thin-bedded sandstones 150 or 200 feet thick; they have the usual aspect of the Vespertine rocks of the Alleghany Mountain.
5. Fossiliferous sandstone, 10 or 15 feet thick.
6. At the summit of the hills a massive white sandstone, 40 or 50 feet thick. This is the Seral white sandstone.

About 4 miles S.E. of the mouth of Brokenstraw Creek, and 3 miles E. from the Alleghany River, there is a bed of coal consisting of two layers, as follows:—

Slaty Coal, 1 foot 6 inches; White Sandstone, 3 to 4 feet; Good Coal, 1 foot; Fire-clay with small balls of iron ore.

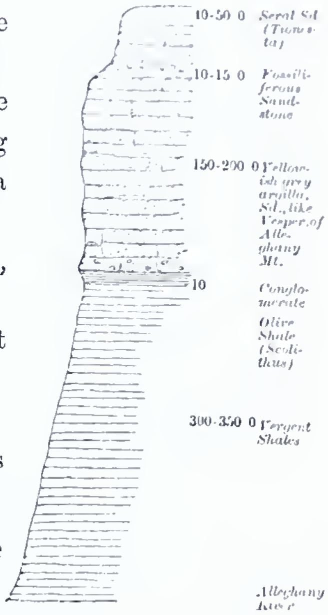

10-50 0 Seral Sd (Tionesta)
10-15 0 Fossiliferous Sandstone
150-200 0 Yellowish grey argilla. Sd., like Vesper. of Alleghany Mt.
10 Conglomerate
Olive Shale (Scolithus)
300-350 0 Vergent Shales
Alleghany River

FIG. 392.—Hills S.E. of Alleghany River, near Warren. 1 *inch* = 200 *feet.*

Many of the hills N.W. of the Alleghany River are capped by the Vespertine conglomerate, the Seral having been washed off.

On the S.E. of Brokenstraw Creek, the very highest hills are capped with a thin covering of Coal-measures containing the above-mentioned twin bed: the elevation of these coal-rocks above the river is between 400 and 500 feet.

Bog Ores.—Several deposits of bog-ore are to be met with in this belt of country: one of these is at the head of a small stream about 4 miles E. of Warren, a little back from the S. bank of the river. The amount of ore was not ascertained, but it did not appear important. Another more considerable body of the ore lies near the main stream of Hickory Creek: this appears to be a tolerably rich one. Other small collections of similar ore are seen N. of the forks of the Tionesta on the Ridgeway Turnpike; but these, and some others that might be mentioned, are too unimportant to be useful.

Very similar to the Tionesta portion of the basin is the geology of that division which lies to the N.W. of the Alleghany River, between Warren and the valley of French Creek.

Seral Conglomerate, North-West Limit.—By an inspection of the Geological Map it will be seen that the N.W. margin of the Seral conglomerate separates naturally into three tracts: that farthest to the N.W., forming the skirts of the basin, consists of a series of detached outlying patches.

The middle tract is a nearly continuous belt extending in a S.W. direction from the Brokenstraw near its mouth to French Creek. The third is formed by a range of broad detached summits, capped by the Tionesta coal, and stretching along the N.W. side of the Alleghany, from below the mouth of the Tidioute to the mouth of French Creek.

The most N.E. outliers of conglomerate are a few small knobs immediately N. of the Brokenstraw, and one near the Little Brokenstraw, 3 miles S.E. of Lottville. Two others of large area lie W. of the main Brokenstraw in Spring Creek Township. The most remote outliers are three low elongated hills in Randolph Township, W. of Centreville. S.W. of these are several small patches in Wayne Township. Two or three lie N. of Sugar Creek Lake, and three more W. of Little Sugar Creek. N. of Meadville are the College Hills, Huidekoper's Hill, and another a mile farther N. Besides these principal isolated tracts containing the rock in site, there are many localities in the district where it occurs in loose angular blocks of considerable size, which seem to have been displaced but a short distance from their original bed. These are most common between Centreville and Meadville.

The more continuous belt of the sandstone, or middle division of the district, is a nearly unbroken table-land throughout all its central portion ; but around the forks of Oil Spring Creek, and again between Sugar Creek and the river, it is broken by numerous valleys and ravines, so as to form a succession of detached summits.

Tionesta Coal Group, North-western Limit.—The only coal-bed of this group hitherto developed with the overlying Tionesta sandstone, occupies a range of six or seven broad and elevated summits on the N.W. side of the river. The most Eastern of these is the river hill, North of Hickory Town ; another spreads from Hickory Creek and the river Westward to Pitthole Creek ; between this latter and Oil Creek there are two other large patches, one W. of the head of Pitthole Creek, and the other nearer the river in Windrock Township. Between Oil Creek and the mouth of French Creek are three other elevated outliers of the coal, the largest lying to the E. of Two-mile Creek ; the next immediately N. of Franklin ; and the third, and smallest, a short distance to the N. of the latter. In all these patches, the coal itself has been opened in only three places ; but the observer may assure himself of the existence of the Tionesta Bed in each of the summits mentioned, by tracing the overlying shale and sandstone strata from one to the other.

The coal has been opened two and a half miles S.W. of Lamb's Tavern, which is 20 miles from Franklin on the road to Warren. Another opening is a little E. of Oil Creek, about a mile N.W. of the same road, and 14 miles from Franklin. Here the seam consists of a black friable coal shale rather than a true coal : it is about 3 feet thick. This locality is on the summit of a hill, and is covered by only 3 feet of soil. A third is 5 miles N. of Franklin, on the Cooper's Town Road. At each of these points the bed does not much exceed 15 inches in thickness. Over it rests 18 or 20 feet of blue shale, capped by the lower beds of the second sandstone. In these several particulars it accords exactly with the same seam, as seen in the Tionesta portion of the basin.

Bog Ore.—A small deposit of bog ore exists near the head-stream of Stewart's Creek, and a coarse nodular ore may be seen in the Warren Road, 3 miles to the N.E. of the mouth of Oil Creek, at the top of the hill, and immediately below the Tionesta sandstone.

North-Western Limit of the Sixth Basin, from French Creek Westward to the Ohio Line.—W. of French Creek a more uniform intensity in the action of the denuding flood has left fewer detached outliers of the carboniferous strata. Thus far the Seral conglomerate, or the sandstone which represents it, has been viewed as the base of the coal series, and the Tionesta coal as the lowest bed. But in the neighbourhood of French Creek, and the country between it and the Ohio line, a new group of Coal-measures comes in under the great coal-conglomerate. A few miles to the E. of French Creek, we first distinguish these earlier members of the coal-formation, consisting chiefly of beds of brown and black shale, containing some few scattered nodules of iron ore and one or more beds of coal. In this vicinity only one bed has been met with, and that of minor importance, but it becomes a valuable seam proceeding Westward. Its distance from the base of the sandstone is variable, but generally increases as the beds which separate them become more arenaceous.

The most Eastern localities where this coal-bed was discovered were those of Pine Knoll in Wayne Township, near Little Sugar Creek, and on the County line one mile S.W. of Sugar Creek Lake. In the former locality it consists of 15 inches of inferior coal, with a dull lustre, separated from the base of the conglomerate by 10 or 12 feet of brown and black shale, through which are scattered a few small nodules of very compact argillaceous iron-ore. The floor of the coal is likewise formed of brown shale, apparently free from nodular iron-ore. At Sugar Creek Lake the bed is about the same thickness, consisting of bituminous slate and impure coal ; it lies at about the same distance from the overlying sandstone, brown shale being interposed.

The whole thickness of these inferior Coal-measures may, in the country around French Creek, be estimated at from 30 to 40 feet.—(See Fig. 393.) When the country to the Eastward of these localities becomes more cleared, this seam will probably be found to extend considerably farther, but probably nowhere as an available bed in the direction of the Alleghany River. It thins out Eastward, and is certainly absent at Oil Creek.

There are many other places, however, in the neighbourhood of French Creek, where this coal might be found by searching for it, at a proper distance below the base of the conglomerate. The particles of coal that have been found in the vicinity of Meadville and elsewhere, beyond a doubt belong to this coal-seam. These fragments have been broken from the edges of the bed on the sides of the hills, and brought down, together with other detrital matter, by the strong currents of water that have contributed to the denudation of the surface of the country. Fragments thus derived, but strewed over the surface of the country in the superficial soil, and there turned up in ploughing the fields around Meadville, have deceived many into the belief that some valuable bed of coal might be opened in the vicinity. Such a bed has been diligently, but, of course, fruitlessly sought, and even at considerable pecuniary loss. Indications of the Sharon Bed, above described, are met with in several places on the high plateau which enters Eastward from the summit of the College Hills, at an elevation of 400 feet above the bottom of the canal, and about 12 feet below the base of the great conglomerate. The interposed strata consist of beds of brown shale.

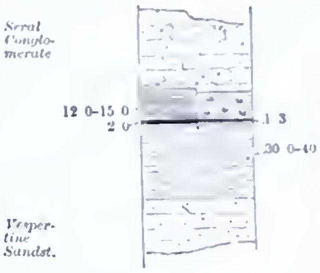


FIG. 393.—Sugar Creek Lake.

Proceeding Westward, the same coal-seam has been found on Deer Creek, in French Creek Township (Mercer County), about 4 miles from its mouth. It is here about 2 feet thick, and less slaty. About 12 or 15 feet of brown shale separate it from the base of the overlying Seral conglomerate sandstone which caps the hill. The coal is said to have been worked for the Meadville market, but the mine is now abandoned.

The high land about the head of Deer Creek, occupying a large part of French Creek Township, is likewise capped by the representative of the Seral conglomerate; and although the underlying Coal-measures were not noticed, their occurrence beneath it may be safely inferred.

In the Western part of Sandy Creek Township is a long ridge of elevated land, commencing about 2 miles S. of Conneaut Creek, and terminating 4 miles S. of Sandy Lake in Mercer County. The greater part of this ridge in Fairfield and Sandy Creek townships is occupied by the Seral conglomerate and the underlying Sharon Coal-measures. After crossing Sandy Creek, which cuts through this ridge, we come upon higher members, of which we will speak presently.

At Georgetown the conglomerate is found forming the highest point of land. The shale between it and the coal contains two deposits of good iron-ore about 1 foot apart—the upper one 7 inches thick, and the other, of a beautiful blue colour, about 5 inches. Beneath this shale containing the ore is the Georgetown Sharon coal-bed, increasing in thickness as we proceed towards the West, although it is by no means regular. In the immediate vicinity of Georgetown it is about 20 inches thick, but about 2 miles towards Greenville it is upwards of 3 feet thick. It is a slaty cannel coal of a dull jet-black lustre, and free from sulphur.

Ten miles N.E. of Georgetown, and from three to three and a half miles due S. of Conneaut Town (on Tract No. 8 of Fielding's Draft), is a small outlying patch of the lower Coal-measures, covered only by a few feet of the lower beds of the Seral conglomerate.

The coal is a semi-cannel coal of slaty structure and peculiar lustre; it is from 3 to 5 feet thick. It is tolerably pure, contains no sulphuret of iron, and is said to be much liked by the blacksmiths. The bed is covered with shale and very argillaceous sandstone 12 feet thick, including one or two seams of iron ore, one of which is about 1 inch thick.

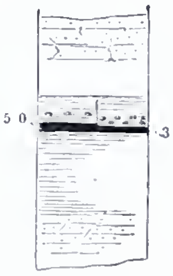


FIG. 394.—Georgetown, and 10 miles N.E.

The bed of coal within the distance of 26 rods, in a S.E. direction, is only 1 or 2 feet thick. It is thin also upon the other side of the summit of the hill, which does not rise more than 15 or 20 feet above the plane of the coal-bed. It is wrought on this account with much difficulty. The selling price of the coal in Meadville varies from 17 to 18 cents per bushel.

Less than a mile S.E. of Greenville commences a broad and rather high ridge, which extends to within a short distance of the Shenango River, where it is joined by another similar ridge coming down from the N.N.E. These converging ridges form two sides of a triangle, occupied by the Seral conglomerate and the inferior Sharon measures.

All the high land around the head-streams of Otter Creek, and between it and the Shenango, are occupied by the same massive sandstone, which, gradually sinking to a lower level as it dips to the S.E., gives way to higher members of the coal-formation as we approach the town of Mercer.

West of the Shenango River.—Upon the W. side of the Shenango, a long ridge of elevated land commences about a mile E. of Kinsman (Ohio), and crosses the State line at the point where the Crawford and Mercer County line unites with it. Two miles from the line it forms an elbow, and then continues, in a nearly S. direction, to the head of a little run which empties into the Pymatuning, 2 miles above its mouth. Here it separates into two ridges, one passing within a mile of Greenville to the great bend of the Shenango opposite Lackawanna Creek; while the other continues its S. course to the Pymatuning. A little S.E. of the termination of the latter ridge, and on the E. side of the little run before spoken of, is a high tract of land nearly 2 square miles in area. The ridges just described are occupied by the Seral conglomerate and sandstone, which, gradually rising towards the N.W., are very sparingly spread upon the highest summits of the ridge in the middle portions of West Salem Township. The underlying Coal-bed has been opened in several places, at a distance of about 15 feet below the Seral conglomerate and sandstone. At Mr Lochslimmer's drift, 3 miles S.W. of the town, the coal is 240 feet above the bottom of the canal, which is about a mile and a half distant. Here also the coal is a species of semi-cannel coal, with a slaty structure and a dull jet-black lustre; thickness about 3 feet. Between it and the base of the sandstone is black bituminous shale, with vegetable impressions. The same seam has been opened four and a half miles to the E. of this, near Orangeville. Here it is about 14 feet below the Seral conglomerate, which rises to a considerable height above it. It is a slaty cannel coal, less than 3 feet in thickness, and has a local dip of 15 feet per mile towards the S.W. A mile and a quarter S. of E. from the last place, and on the Five-hundred-acre Tract of Captain Duncan, search has been made for this coal, and seven pits have been sunk at different levels, from which the following section has been made:—

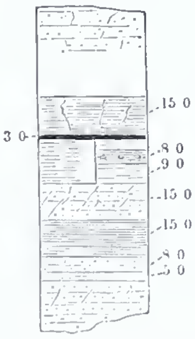


Fig. 395.—Two miles E., and three miles S.W. of Sharon.

Soil, 8 feet; Brown Shale, with a little iron ore, 8 feet; Black thinly-laminated Shale, 9 feet; Yellow and brown Sandstone, with vegetable remains, 15 feet; Black Shale, 15 feet; Slaty Sandstone, 8 feet; Brown Shale, 5 feet; lastly, Silicious Conglomerate, 60 feet underneath the true level of the coal, which was nowhere discoverable.

On the hills on the S. side of the Shenango, below the mouth of the Lackawanna, and about 6 miles N.W. of Mercer, coal has been found on the land of Mr Robert Flute; and 260 feet above the bottom of lock No. 15, overlooking the river, the hill itself rises 60 or 80 feet higher. Here the following section was obtained (see Fig. 396):—

Seral conglomerate; Sandstone, yellow, flaggy, fossiliferous, 5 feet; interval (containing Sharon coal?), 10 feet or more; Shale, black, brown, with iron ore, 7 feet; *Coal*, 8 inches (Sharon coal?); Grey Sandstone, slaty, with vegetable remains, 7 feet; Dark-coloured Shale, 16 feet; *Coal*, 15 inches; Shale, black, yellow, and brown, 15 feet; *Coal*, 2 inches; Chocolate-coloured Sandstone, 1 to 2 feet; Black bituminous Slate, 9 inches; *Coal*, 24 to 30 inches.

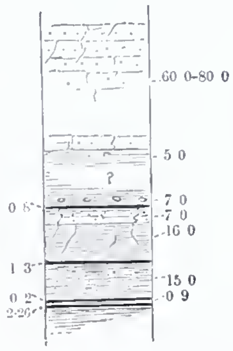


Fig. 396.—Six miles N.W. of Mercer.

A few hundred yards to the S.E. of this, on the other side of the summit, another shaft has been sunk to a considerable depth, without revealing any indications of the 2-feet coal-seam. Conjecture is at fault upon the identity of either of these beds with the Sharon coal, already described.

One mile N. of this locality, on the opposite side of the Shenango, several excavations have been made. Neither the 2½ feet nor the smaller seams above were found, although in other respects the stratification appeared to be very similar to that given in the preceding account.

Less than 2 miles E. of Sharon, on a high ridge, is a coal-seam 4 feet in thickness.

Below it are a few inches of bluish clay, and beneath that a hard, fine-grained, brittle white sandstone. The exposures are imperfect, but the coal is believed to be the same as that of Sharon.

About 2 miles W. of this last locality, on the opposite side of the deep ravine of the Shenango, is a high ridge, in which the Sharon Coal-bed has been opened, and skilfully and extensively wrought. The coal is near the top of the ridge, capped by the Seral conglomerate, between which and the coal are brown and blue shales, with argillaceous sandstone, 10 feet of which are exposed. The bed is 4½ feet thick, with a floor of black and brown shale (10 feet thick) resting upon grey slaty sandstone, and below that a coarse conglomerate formed of white pebbles of quartz. On the W. side of the ridge, at the distance of about three-fourths of a mile, the same coal is seen to outcrop 16 feet higher upon the E. side, showing a dip S.E. of 20 feet to the mile. The coal is probably 300 feet above the Shenango.

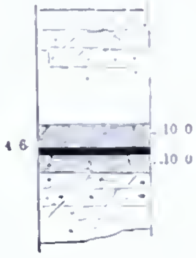


FIG. 397.—Curtis's Coal, Sharon.

The coal obtained at Clarksville is from the same bed, and is in every respect similar to it: it is good coal, free from sulphur, and occurs in masses of considerable size.

This seam is known to extend for some distance into the State of Ohio, and is probably the same with the Warren and Akron Coal-bed.

Some indications were seen of the final dying-down of an axis which would pass near the mouth of Mosquito Creek, having a S.W. and N.E. course; but as this did not cross into the State of Pennsylvania, no time was spent in ascertaining its existence; details connected with its appearance would, however, probably account for the line of outcrop of the coal-formation taking a more E. and W. course after crossing our W. State line. What becomes of the coal when the dip sinks it down to water-level towards the S.E. is not known. No indications were seen of it between Sharon and Pulaski, and at the latter place the conglomerate is but little above the water-level. It is not at all improbable that a bed of coal which has exhibited so much irregularity elsewhere should have altogether thinned out, or should exist only at undiscovered intervals. This want of uniformity appears in many places to mark in some measure the earlier periods of the coal-formation; for in the succeeding strata, which lie between the Seral conglomerate and the Tionesta sandstone (to be further described), very general confusion and want of regularity exist, both with regard to the coal-beds themselves and the strata which separate them.

We continue the details of the Tionesta group of Coal-measures above the Seral conglomerate, by returning to the neighbourhood of Franklin.

CHAPTER XIII.

THE NORTH-WESTERN SIDE OF THE SIXTH BASIN—(*Continued*).

THE TIONESTA COAL, FROM FRANKLIN WESTWARD.

THE strata enclosed between the Seral conglomerate as their base, and the Tionesta sandstone as their upper limit, increase considerably in thickness W., and contain in Mercer County the most valuable bed of coal which there occurs. On both sides of the Alleghany River we see the Seral conglomerate, for several miles below the mouth of French Creek, at a considerable elevation above the water-level, standing out in bold relief upon the river-hills. No exposures occur underneath it for a space of 50 feet, at which level the Vespertine sandstone usually begins. All the country on the S.E. side of the Alleghany River, for 6 or 8 miles back, between the Tionesta and the mouth of Scrubgrass Creek (16 miles below Franklin), is occupied by the conglomerate and the Tionesta sandstone, with their intermediate shales and coal-beds. This tract, however, affords few or no exposures, and, with the exception of the deep ravines, like those of Horse and Hemlock creeks, is covered with a stunted growth of chestnut timber. The country lying N.W. from the Olean Road, about the heads of Racoon Spring and Millstone creeks, is overspread by the same rocks, and is but a continuation of the country lying to the N. of the Tionesta. The want of exposures, owing to the uncleared state of this part of the Sixth Coal-basin, has prevented the collection of many facts relating to it. The Tionesta Coal is supposed to exist here between the two sandstones, but is not seen until we come into the neighbourhood of Tionesta village, where it has been opened. To the S.W. of the Tionesta, exposures are hardly more frequent. The Tionesta sandstone overspreads the general level of the country, and indications of the coal below it appear on Hemlock Creek. The coal seen in the vicinity of the heads of Pine Creek and Red Run belongs to this seam, as also that 6 miles S.E. of Franklin, on the turnpike. Here the coal is opened about 25 feet below the summit of a little knoll of black and brown shale, and proves to be a true cannel coal, about 20 inches thick, of good quality, burning freely, and looking much like slate, with a peculiar fracture and lustre, and containing vegetable impressions.

Bog Ore.—Upon Hemlock Creek, 3 miles from its mouth, there is a bank of bog-ore of considerable extent. It is said to cover 4 acres, and to be about 14 feet thick in the middle. Three beds of bog-ore occur 6 miles below, upon Horse Creek; they cover about 3 acres each. A bank of hard ore was at one time opened about 2½ miles from Horse Creek Furnace, and 3 miles from the river. The ore occurs in shale, and consists of nodules from 6 to 10 inches in diameter, with a thin black crust on the outside, and a yellowish nucleus. The opposite side of the Alleghany River, between Franklin and the mouth of Scrubgrass Creek, has been more fruitful in exposures than the country we have just passed over. For the first 5 miles, however, back from the river, fragments in great abundance have been detached from the Tionesta sandstone, and, sliding down the sides of the hills, have obscured in many places the strata which occupy a lower position. In French Creek and Sandy Creek townships, therefore, the strata which occupy the intervening space between the Seral conglomerate and the Tionesta sandstone have been traced with great difficulty.

The Tionesta Coal-bed is twice exposed—upon the river below the mouth of Six-mile Run, and 4 miles S. of Franklin.—(See Fig. 398.) At the latter point we find two veins, probably from 30 to 40 feet apart: the lower one rests upon brown shale, which is immediately above the Seral conglomerate. The coal itself is thin and poor; above it is argillaceous sandstone. The upper bed is a cannel coal, and enclosed in shales, over which is the Tionesta sandstone. The coal found on the E. side of the Alleghany River, and in the basin of the Tionesta, is supposed to be the continuation of the upper of these two beds. On a hill bounding Sandy Creek, and E. of the road from Franklin to Scrubgrass Creek, the Tionesta Coal has been discovered near the top of the hill. It is thin, and a considerable mass of the Tionesta sandstone rests above it.

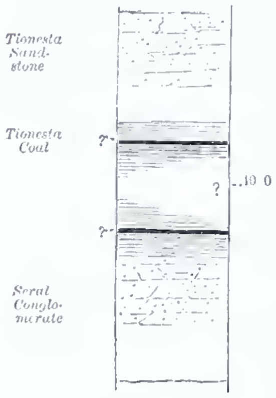


Fig. 398.—Four miles S.W. of Franklin.

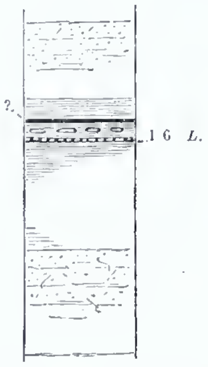


Fig. 399.—Three miles W. of Sandy Creek Furnace.

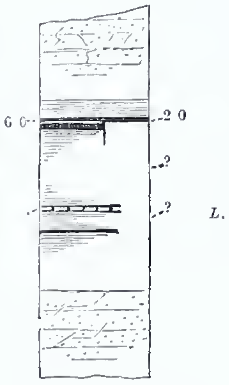


Fig. 400.—A. Henderson's, Law's, &c.

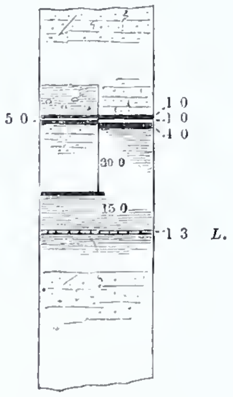


Fig. 401.—Sandy Lake.

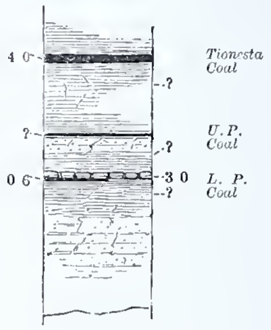


Fig. 402.—Three miles E. of Mercer.

Bog Ore.—At Sandy Creek Furnace, several small deposits of bog-ore are seen at the base of the Seral conglomerate, beneath which they have issued. One of the deposits lies upon a terrace of the hill behind the Furnace, and about 150 feet above the level of the Creek; it covers about three-fourths of an acre, and is from 3 to 11 feet deep, but averages, perhaps, about 4 feet over the whole area. The ore is bright yellow, light, with fine crusts, and commands at the Furnace 25 cents per ton. Three miles W. of the Furnace, hard ore, belonging to the same proprietors, is exposed at a distance of 25 feet beneath the base of the Tionesta sandstone, above a bed of blue argillaceous fossiliferous limestone, 15 inches thick. Above it are the following strata, ascending: Nodular iron-ore, 3 inches, immediately upon the limestone; brown shale, 3 feet; ore, 3 inches; brown shale, 2 feet; ore, 2 inches; coal doubtful—thin if present.—(See Fig. 399.) At Rheno's Furnace, on Big Sandy

Creek, bog-ore has likewise been found at the base of the conglomerate: it covers half an acre, and is about 10 feet deep. Its colour is dark, and if used with hard ore, in the proportion of three parts of the former to one of the latter, it is said to make good iron. Indications of the Sharon Coal-bed were noticed a short distance below the base of the Seral conglomerate. The hard ore, used at both the furnaces, comes from the shales belonging to this inferior coal group. These shales are situated below the level of the coal-seam, and are chiefly brown-coloured, coarse-grained, and sometimes sandy. One of the localities where it is mined by benching—Sandy Creek Furnace—is about three-quarters of a mile S.E. of the works, and is situated on the level summit of a hill. Brown shale and soil have been thrown out to the depth of 5 or 10 feet. The ore is of the small nodular variety, and only tolerably good. The other place is 2 miles S. of the Furnace: this is likewise on the broad level summit of a hill. Above the ore are 5 feet of brown shale and clay, covered by soil. The ore consists of two varieties—the blue-clay ironstone, in flat nodules, from 18 to 24 inches by 12 broad, and about 4 inches thick; and the small nodular kind, consisting of brown and black crusts, with a nucleus. The former is fine-grained, blue, homogeneous in texture, compact and heavy, containing sometimes particles of white spar, which are dispersed throughout it. The hard ore of Rheno's Furnace is obtained about 2 miles from the Furnace on the creek: it is found on the top of a hill, as in the other localities, and in the same bed of brown shale; nor does the ore differ materially from the others. The shale is probably thicker here than further N., in the neighbourhood of Meadville and Sugar Creek Lake. The Sharon Coal is said to have been found beneath the conglomerate, in the hill on the S. side of Sandy Creek, near where the Franklin and Mercer Road crosses it. W. of Rheno's Furnace, on the Mercer Road, Mr J. Adams once opened a drift on the Tionesta Coal-seam.

About three-quarters of a mile E. of the county-line this bed is much better exposed: it is here 2 feet thick, and covered by black and brown shale, but has been opened half a mile farther S., 6 feet thick. At the latter place the dip has brought it down to a lower level. Its divisions read as follows: Shale; Coal, 9 inches; Clay, 3 inches; Coal, 5 feet, with some sulphuret of iron, but good.—(See Figs. 400 and 401.) Above it rises the massive outcrop of the Tionesta sandstone, half-way up the hills, capped by a small coal-bed (the Brookville Coal), opened, but unfit to work, a fourth of a mile farther W.

The lower Porter Coal-bed appears upon the Sandy Creek Hills. Above it is seen a bed of blue argillaceous limestone, similar to that already mentioned as underlying the Tionesta Coal.—(See Fig. 400.)

Henderson's Drift, in Mercer County, half a mile from the Venango line, is undoubtedly on the Tionesta Seam, and the high land between the heads of Little Sandy and Mill creeks likewise contains it. It has been worked near the source of the latter stream, N. of the Franklin and Mercer Road, where it rests upon and is covered by brown shale.—(See Fig. 401.)

In the neighbourhood of Sandy Lake the Tionesta Coal-bed is well developed. At the former locality there are about 5 feet of good coal, covered by brown shale, which contain a few thinly-scattered nodules of argillaceous ore. Beneath the coal is a yellow sandstone, sometimes argillaceous. Under this is a crushed coal-bed, 30 feet beneath the Tionesta Coal, and a continuation of the Upper Porter Bed. This is the most Eastern opening of the bed yet known; but it is not here workable.

Fifteen feet beneath the Upper Porter Coal is the blue argillaceous, fossiliferous limestone, 15 inches thick, containing chiefly Leptæna and elongated concretions of iron, from a fourth to half an inch in diameter, and from 3 to 6 inches long. Under the limestone is shale, which rests upon the representative of the great conglomerate.

The hill is capped by the Tionesta sandstone. About half a mile W. of Brown's Bank, and still on the S. of the lake, a drift was opened on the same bed. The shale which usually overlies the coal is here wanting, and the Tionesta sandstone rests immediately upon the coal. The bed measures in all 6 feet, the upper 12 inches being separated by 12 inches of clay from the 4 feet of good coal below: the floor is shale. From the coal-bed down to the lake, a vertical depth of 100 feet, no exposures are seen.

On the N. side of the lake the same seam has been opened; the associated rocks are the same.

On Cool Spring Creek the limestone has been found sufficiently thick to be worked for the lime-kiln. It is bluish or grey, and earthy in its appearance.

The Lower Porter Coal-bed, 5 inches thick, is seen immediately underlying the limestone, which is exposed at Crill's Mill, 3 miles E. of Mercer Town, where it is 3 feet thick, slaty, earthy, and of a dark-blue colour, containing Producta and other fossils in abundance. Here, instead of coal, we see from 2 to 3 feet of black bituminous shale beneath it, representing the Lower Porter Bed.

At Crill's Mill, 3 miles E. of Mercer (see Fig. 402), we have the following section :—

Brown Shale ; Coal, 4 feet (Conolly's) ; Sandstone and Shale. Coal, small and crushed (Upper Porter Bed) ; Sandstone ; Shale. Limestone, 3 feet. Black bituminous Shale, 2 or 3 feet (Lower Porter Coal) ; Brown Shale ; White flaggy Sandstone.

The Conolly opening on the Tionesta Coal is near the top of the hill ; the coal is good, but wrought to disadvantage. Dip a little to the E. of S., but occasionally locally reversed. The drifts should always run in N.W.

There is a higher point of ground, half-way between Conolly's and Mercer, where this seam might be opened on the S.E. side of the hill. The spot where it outcrops is marked on the N. and W. side by the issue of several springs of water. It is a little higher than the level of Conolly's Drift.

CHAPTER XIV.

NORTH-WESTERN BORDER OF THE SIXTH BASIN—(*Continued*).

MERCER AND THE BEAVER RIVER.

The hill upon which the town of Mercer stands exposes sandstone and shales, but neither the limestone nor coal-beds of the Tionesta group have been discovered in it, although within 1 mile to the W. they are extensively wrought. One faint coal-smut, the outcrop of a small bed struck in sinking a well in the outskirts of the town, appears upon the hill-side near the summit, but cannot be identified. It may possibly prove to be the Tionesta Bed, greatly thinned away ; a vein made probably by the appearance of the limestone upon the turnpike, 1 mile S. of the town, at a low level. It is there from 12 to 15 inches thick, and has the Lower Porter Bed (from 12 to 20 inches thick) below it.—(See Fig. 403.)

On the hill some distance higher up the run, we see fragments from the Tionesta sandstone bed. Farther down the turnpike on the Mercer side of the Toll-gate the same limestone may be traced in the meadows. This shows a decided dip to the S.E.

Wright's Coal-bank is the first W. of the town, and that from which the chief supply of fuel is obtained. The level of the opening is a little lower than that of the Court-house. From 20 to 25 feet of black and brown shales overlie the coal, the black shale containing some minute fossil-shells. The coal is 5 feet thick, light, compact, and good. At Porter's Drift the bed is 6 feet thick, but subdivided by a band of black slate from 6 to 12 inches thick. The coal is not so pure as elsewhere.

At Davis's opening the bed yields 2½ feet of good sound coal. On the same tract, 63 feet below the coal-level, we see the Mercer limestone. It is not well exposed, but the pieces lying near are of a dark colour, with abundance of minute fossils. The strata between it and the Mercer Coal, a fourth of a mile farther W., are, as we descend the hill to the Lackawanna (see Fig. 403), as follows :—

Soil ; Brown Shale, 5 feet ; Black Shale and fossil Shells, 17 feet ; Fire-clay, 1 foot. *Tionesta Coal,* 5 to 6 feet ; Fire-clay, 2 feet ; Black and brown Shale, with argillaceous Sandstone, 30 feet ; Black Shale, 4 feet ; Sandstone, with vegetable remains, 1 foot ; Black bituminous Shale, 2 feet. *Upper Porter Coal,* 1 foot ; Fire-clay, 2 feet ; Black and brown Shale and Sandstone, 6 feet. *Middle Porter Coal,* 1½ feet ; Sandstone, 6 feet ; Bluish and brown Shale, with iron ore, 14 feet. *Mercer Limestone,* 1½ feet ; *Lower Porter Coal,* 1 foot ; Blue Shale, with iron ore.

We have here a striking contrast between the 50 feet thickness of intervening shales and sandstones and the coal-bed of the Tionesta region. Yet when the series shall have been thoroughly examined, the same variable alternations of carbonaceous and non-carbonaceous materials may be developed there as here.

A mile and a quarter farther W., a similar section (Fig. 404) was obtained as follows:—

Tionesta Sandstone, 50 feet; Black Shale or Clay, 1 foot. *Tionesta Coal,* 4 feet (shale in the middle); Fire-clay, and blank interval, 46 feet. Blue Shale, 11 feet. *Coal,* 9 inches; Brown Shale, 2 feet. *Limestone,* 18 inches. *Lower Porter Coal,* 1 foot; Bituminous Shale, 2½ feet. *Coal,* 1½ feet; Shale, 10½ feet. Brown Sandstone, 63 feet, which is the representative of the Seral conglomerate.

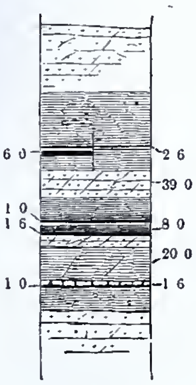


FIG. 403.—Mercertown.

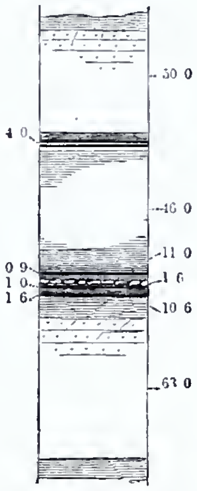


FIG. 404.—Jenkin's Mill.

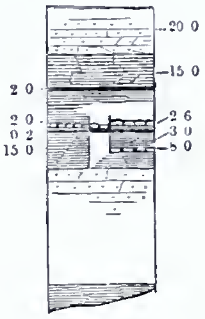


FIG. 405.—Mr Porter's.

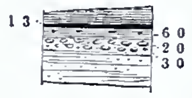


FIG. 406.—Neshannock Creek.

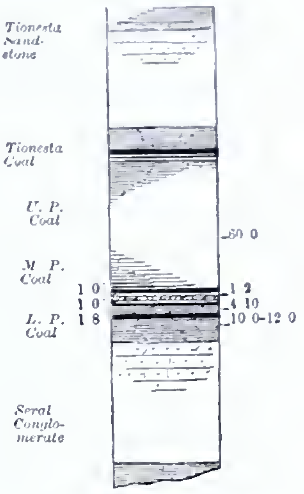


FIG. 407.—Two miles W. of Mercer.

The Lower Porter Bed is wrought 3 feet thick on Mr Porter's farm to the right of the Sharon Road. The limestone lies upon it, and, including a few inches of calcareous shale, is 4 feet thick. But both coal and limestone change their respective thicknesses incessantly. Thus the following section (see Fig. 405) was made within a few hundred feet of the last:—

Brown slaty Sandstone, 20 feet; Shale, 15 feet. *Middle Porter Coal,* 2 feet; Slaty argillaceous Sandstone, passing downwards into shale, 12 feet. *Mercer Limestone,* 2 feet. Shale, with a 2-inch-thick seam of coal, 15 feet.

Again, at Porter's Bank, the strata appear thus:—

Soil and diluvium, 15 to 20 feet; Rotten Calcareous shaly Rock, 3 feet. *Limestone,* 2½ feet. *Coal,* 3 feet; Shale, 8 feet.

Here the coal is light and good. Beneath the 8 feet of shale appears an unknown limestone. The shale, both above and below the limestone and coal, contains a considerable quantity of argillaceous iron-ore in small scattered nodules. This is the case on the Sharon Road, where the lower shale-bed is usually a bluish or brown rock, containing some non-continuous bands of argillaceous sandstone. This bed is seen at Jenkin's Mill, 2 miles below Mercer, near the water-level of the Neshannock Creek, where the following section (see Fig. 406) was compiled:—

Shale, containing nodular ore. *Coal,* 15 inches; Light Shale, with ore; Black Shale, with ore, 2 feet; Shale, 3 feet, with five layers of nodular ore; Sandstone, with vegetable remains, extending 6 feet to water-level.

This is the Seral conglomerate. The ore has been wrought at Springfield Furnace, where the Tionesta sandstone is finely exposed—sometimes as a conglomerate, with pebbles as large as a common pea.

About 2 miles W. of Mercer, on the Micheltree Road, there lies, between the Tionesta Coal-bed and the Tionesta Sandstone, but an inconsiderable thickness of shale, the sandstone being about 50 feet thick.—(See Fig. 407.) The coal-bed at Lafferty's and Adam's is divided by a bed of black slate, from 12 to 15 inches thick, as at Porter's, with this difference, that at the latter drift the band of coal beneath the slate is thicker than that above, while, at the former places, the greatest thickness belongs to the upper band. The slate-band gradually approaches the bottom of the coal-bed as we proceed W., until it at length entirely shuts out the lower coal-member, and permits the upper to become the whole bed at the Shenango Creek.

The limestone in this neighbourhood is to be seen about 60 feet below the coal, and may be well studied on Law's farm. Two feet above it is a small bed of coal, less than a foot in thickness, upon which rests bluish shale. Beneath the limestone we have,—

Coal, 1 foot; Black Bituminous Shale, 1½ feet; Brown Shale, 14 inches; Black Bituminous Shale, 7 inches; *Coal*, 20 inches.

Twelve or fourteen feet beneath the lowest coal appears the top of the Seral conglomerate. These mines may be said to mark the last outcrop of the beds of the Tionesta Group toward the N.W.

Seven miles W. of Mercer, on the Sharon Road, the top of a high ridge receives the Tionesta Coal-bed within 20 feet of the summit, while below it appear fragments of the limestone stratum. The coal is evidently a workable bed at this its last appearance. On Hog-back Run, 4 miles or more S. of Sharon, and about 2 miles from its entrance into the Shenango, on its E. bank, the Mercer Limestone and its underlying coal again appear. The limestone lies in blocks in the stream, and the shale beneath it contains a considerable quantity of blue nodular iron-ore. The limestone is seen again farther down the Shenango, near Paoli, generally sinking to a lower level.

In the neighbourhood of Newcastle, three tolerably complete sections were obtained (see Figs. 408, 409, 410.) The following is from a stream emptying into the Neshannock, 2 miles above the town, on the W. side of the Creek (see Fig. 408):—

Tionesta Sandstone, 50 feet; Iron Ore, 6 inches. *Limestone* and Chert, 2 feet; Interval, 8 feet; Blue Slate, 2 feet; Clay, 6 inches; Black Shale, 1½ feet; Light-coloured Shale, 3½ feet. Light-blue Shale, with bands of sandstone, 4 or more feet. Interval, 6½ feet. *Mercer Limestone*, 1½ feet. Light-coloured Shale, with sandy seams, 5 feet. *Coal*, 6 to 8 inches, *bituminous*. Slate, 2 feet; Bluish crumbly Shale, 2½ feet. Greyish rotten Sandstone, with vegetable impressions, 1½ feet; Sandstone, flaggy, 8 feet; Brown Shale, 5 to 6 feet; Bituminous Shale, 1½ feet; Bluish or grey slaty Sandstone, with much vegetable matter, 5 feet; Sandstone, 70 or more feet (Seral conglomerate).

We here see the two great sandstones separated again by an interval of only 61 feet. The coals above the Mercer Limestone are gone, or represented by bituminous shale; another limestone, accompanied by black flint and a hard silicious iron-ore, is now first noticed as occurring at the base of the Tionesta Sandstone. There is but one interval, of 8 feet, where the Tionesta Coal could conceal itself, and this occurs in the proper position; but it is more probably represented by 1½ feet of bituminous slate.

The following section, made at a point about a mile N.W. of Newcastle, on a little run emptying into the Shenango (see Fig. 409), shows that conformity of one section to another, where obtained at different localities, though of the same series of beds, is not to be expected in the lower portion of the great Coal-formation:—

Tionesta Sandstone, 50 feet. *Coal and bituminous Shale*, 3 inches; Brown and blue Shale, 1 to 6 feet. *Limestone*, cherty and ferruginous, 2 feet. *Coal*, 12 inches; Light-coloured Shale, blue at the top, 6 to 8 feet; Argillaceous Sandstone, 2 feet; Light-coloured Shale, 12 to 13 feet. *Bituminous Shale and Coal*, 4 feet; Blue sandy Shale, 6 feet; Flaggy Sandstone (S. C.), argillaceous at top, 75 feet or more.

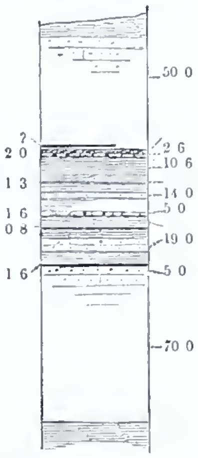


Fig. 408.—Two miles above Newcastle.

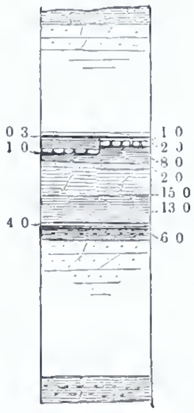


Fig. 409.—One mile N.W. of Newcastle.

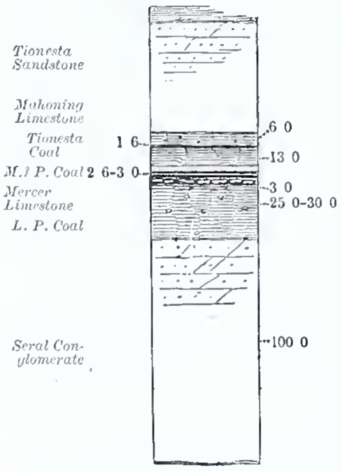


Fig. 410.—Two miles below Newcastle.

Beneath the main Seral conglomerate appears a bed of brown shale, containing ore well exposed, at the W. end of the bridge over the Shenango. This ore, with that described repeatedly in the last chapter as accompanying the Sharon Coals, may very properly be considered the representative of the upper red-shale ore, assuming still greater importance in connection with a lower coal-series on the borders of Virginia, and along the line of Chestnut Ridge.

Sections 408 and 409 are less than 3 miles asunder, although displaying so great a diversity in the series of the beds. Compare the lower coal, &c., in the vertical columns, 403, 404, and 407, with those of 408 and 409. In section 409 the lower limestone may have been overlooked.

The upper limestone will be called hereafter the Mahoning limestone, because well developed along that river: it is well seen in the runs that empty into the Mahoning, some 5 or 6 miles above its junction with the Shenango, where the series of strata does not differ materially from that given in the last section. W. of the State line the iron ore which accompanies this limestone has been mined.

At the junction of the Mahoning and Shenango creeks, the Seral conglomerate sandstone is well seen, and also in the immediate vicinity of Newcastle. In some portions it is highly argillaceous, but above the middle of the bed it is thick-bedded, soft, and but little mixed with argillaceous bands. Its whole thickness is about 100 feet. The Tionesta measures average 60 feet, and the upper or Tionesta sandstone, which is more solid in this locality than the Seral conglomerate, may be estimated at about the same thickness. The distance of the upper surface of the Tionesta sandstone above the Neshannock, at Newcastle, was found by levelling to be 240 feet: the lowest 20 feet consist of shales, seen at the bridge at the W. end of the town.

At Big Run, 2 miles below Newcastle, the following imperfect section (see Fig. 410) was compiled:—

Tionesta Sandstone; Blue Shale with iron ore, 6 feet. *Coal*, 1½ feet; Blue Shale, 8 feet, very argillaceous; Rotten Sandstone, 2½ feet; Blue and brown Shale, with 2½ feet of sandstone at the bottom. *Bituminous Shale*, from 2½ to 3 feet. *Mercer Limestone;* Shale, 3 feet, blue; Shale, with concretions of iron ore; Interval, 25 to 30 feet.

Seral Conglomerate Sandstone.—Down the Beaver River the rocks are not well exposed. The Seral conglomerate sandstone passes under the water-level above the mouth of the Conequenessing Creek. At Wompum Hill, a bed, supposed to be the Mahoning Limestone, is seen 42 feet above the Beaver River. At the mouth of Conequenessing the Tionesta Sandstone is seen on the hill, where large blocks are lying about the surface, and on Slippery Rock Creek, from its mouth up to the bridge at the Mercer Turnpike: there it passes under the water-level. From the mouth of the Conequenessing down toward Brighton, the Tionesta Sandstone may be seen on both sides of the Beaver River, declining gradually to a lower level, until at length it sinks into the bed of the river, and forms the upper fall above Old Brighton.

On the Eastern side of the Beaver, a little above the falls, some of its beds are divided diagonally by curiously undulating lines, which are probably lines of deposition; these belong only to certain beds, and rarely pass from one bed to another. Generally speaking, the stratum so disposed is separated from the next similar stratum by one or more thin layers of sandstone, destitute of these transverse lines, all of which have an E.N.E. and W.N.W. strike, dipping nearly W.N.W.

CHAPTER XV.

SIXTH BASIN IN JEFFERSON AND CLARION COUNTIES; COAL-BEDS ABOVE THE TIONESTA SANDSTONE.

Some of the hills between the Tionesta and Racoon creeks seem high enough to receive the first or second beds above the Tionesta Sandstone, although in the wilderness condition of the country this could not be experimentally proved. It is certain that these beds overspread much of the region between Racoon Creek and the Clarion, some of the higher hills containing rocks even as high as the Ferriferous Limestone. The most northern locality in the basin in which this rock has been discovered, is near the Forest County boundary, and upon the central line of the basin, about 5 miles N.W. of the fifth axis. Fragments of it lie about the soil, accompanied by pieces of iron ore and lumps of chert.

The Clarion Coal-Bed is seen beneath it 30 feet; below which, at an equal distance, is the place for the Brookville Coal, not here discovered; 10 feet more bring us down to the top stratum of the Tionesta Sandstone. —(See Figs. 411 and 412.)

The Clarion Coal-bed at its outcrop on Leach's Farm, in Farmington Township, is 4½ feet thick, and good; roof brown shale, 4 feet. Again, 3½ miles to the S.E. it is 4 feet thick, good, but slightly pyritous. Again, 1 mile to the E. it seems to be but 2½ feet thick; quality good: the roof is shale, 25 feet thick.

The Brookville Coal is here traced with difficulty. It is seen 2 miles N.W. of Leach's, from 18 to 20 inches thick; 30 or 40 feet of brown shale and argillaceous sandstone lie between it and the Clarion Coal, and a few feet of the same rock below it, to the Tionesta Sandstone.

The Clarion Coal and Ferriferous Limestone occur, at Copp's Settlement; 1½ miles N. of the Settlement; at Henley's, 1 mile W.; at the Meadows, at the head of Six-mile Run, 5 miles W. of the Settlement; and on the Eastern limit of the basin E. of the Jefferson County line, and a little back from the Clarion River, where exposures are rare and imperfect. The Tionesta Sandstone arches over the fifth axis as a surface rock, occupying even the highest grounds, along a strip of country 4 or 5 miles wide.

In the bed of Mill Creek and all the streams which empty into the Clarion on either side, but more especially those which, having their source in the Fifth Basin, cross the axis and flow into it from the S.E., the massive rocks of the Seral conglomerate are exposed, and the underlying Vespertine and Vergent series are seen in the deep gorges of Spring Creek and the Clarion River, and in Laurel Run, and above the mouth of Mill Creek.

Bog Iron-Ore.—The base of the Seral conglomerate is the position at which we find the chief bog-ore deposits of the Clarion.

Several of these deposits occur in the vicinity, and on the W. side of the Clarion in Farmington Township, and are worthy of notice. They are about a mile below the mouth of Laurel Run; and upon the opposite side of the river, between two small streams, from 5 to 10 acres are covered with this ore. The deposit at Allsbach's is said to be three-fourths of a mile long. Two miles N. of this there is another extensive deposit of the same iron ore. On the opposite side of the Clarion, up Laurel Run, there are several other deposits more or less extensive.

On some of the higher hills in the neighbourhood of the village of Corsica, upon the Jefferson County line, where the Brookville Turnpike crosses it, the Freeport Limestone has been found within a few feet of the surface. One of these hills is near the turnpike, a mile E. of the town. The Ferriferous Limestone is commonly found at the base of the hills.

Few attempts were made to trace the exact outcrops, or to refer the different coal-drifts to their respective seams in the country bounding the Clarion above Mill Creek. The hills, which are sufficiently high to reach the base of the Ferriferous Limestone, everywhere contain two coals, the Clarion and Brookville beds. Many of the hills which are not high enough for the former, contain the latter; and both of them, together with the superposed limestone, crop out in a line running nearly parallel to the axis, from the Clarion about 2 miles above the Jefferson County line to Mill Creek, 3 or 3½ miles back from its mouth.

The Ferriferous Limestone at its outcrop is only seen in a few rounded isolated knobs, which are easily recognised, and have a somewhat regular range corresponding to that of the axis. It is accompanied by its characteristic chert and iron ore.

The limestone and underlying coals are well seen 5 miles below the mouth of Laurel Run, on Paint Creek, and at the top of another high knoll, 1 mile below the mouth of Laurel Run in Farmington Township.

The Buhrstone or Chert at these localities is abundant, compact in texture, grey externally, light blue when fractured, and covers the surface with fragments from 3 to 12 inches in diameter. The Brookville Coal is seen below it.

The same beds occur on many knolls between Laurel Run and Strattonville. The chief obstacle to an easy discovery of it arises from the fact that the limestone, when thin, is easily decomposed; it is not apt to form a bench or terrace along the slopes.

As the basin deepens S.W., this system of beds gradually descends to the base of the isolated hills, and finally overspreads the whole country. Many of the hills in Paint Creek Township, and about the heads of Deer Paint Creek, embrace an ore capped by the limestone, and at a lower level show the Clarion and Brookville coal-beds.

At *Lucinda Furnace*, on the high ridges on each side of Deer Creek, the limestone is seen capping the hill, accompanied by the chert and iron ore. At the ore-bank about 1½ miles S.E. of the Furnace, and near the level top of the hill, the stratification is as follows:—

Clay, covered with soil, from 4 to 5 feet. *Iron Ore,* from 6 to 24 inches. Chert; limestone. (See Fig. 412.)

The ore is variable in its characters, being sometimes a solid, hard, blue fossiliferous stratum, looking like limestone, while at others it consists of crusts or shells, containing cavities and concentric nodules. These nodules are sometimes 9 inches in diameter, and contain a yellowish nucleus, surrounded by a hard black crust a fourth of an inch thick. The chief part of the ore, however, does not consist of regularly-formed nodules, but of small crusts, which look like fragments of larger masses, and break into small pieces. These frequently contain cavities filled with an unctuous dark-coloured fluid, which escapes when the shell is broken. The inside of these crusts is usually smooth, sometimes of a beautiful glossy black colour, or covered with minute yellow, purple, or violet-coloured crystals: this is most common nearest to the chert. In the upper part of the ore stratum, the shells are much mixed with yellow clay, which itself contains much peroxide of iron. Between the limestone and the ore lies the chert, which passes sometimes into one, sometimes into the other, in which latter case it is often highly coloured by the peroxide of iron. The limestone is known to exist at places several miles to the N. and N.W.

On the hill opposite the Furnace a coal-bed has been opened, from 4 to 5 feet thick, of good quality, and 40 feet below the limestone, at the summit. The same bed is wrought 1 mile S. of this. It is a question whether this is the Clarion or the Brookville Coal.—(Compare Figs. 411, 412, and 413.)

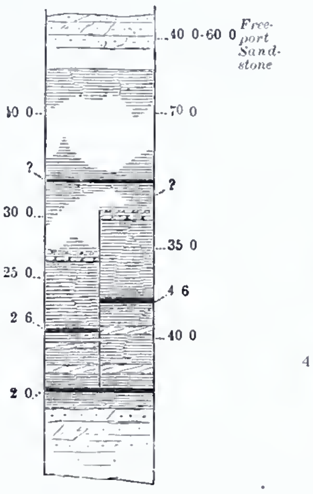


FIG. 411.—Racoon Creek, Clarion River.

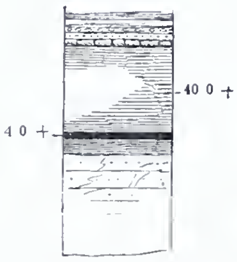


FIG. 412.—Lucinda Furnace.

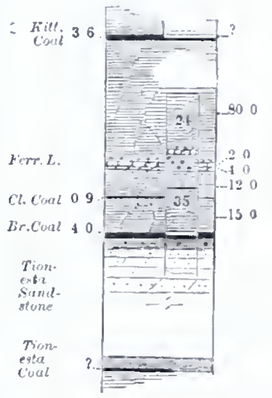


FIG. 413.—Strattonville (three Sections).

Bog Ores.—On land belonging to Lucinda Furnace on Paint Creek, two bogs have formed from ore issuing from beneath the Seral conglomerate, each covering half an acre of ground, and from 2 to 8 feet deep.

Four miles N. or W. of Lucinda Furnace, the Ferriferous Limestone and its ore have been dug or benched away over an area of more than an acre, upon the summit of a very high hill. Over them lie blue and brown shales 4 feet thick. The ore is chiefly shell-ore; the limestone dark-blue and heavy.

In the deep gorges of the Clarion River, and most of the larger streams that empty into it, the massive sandstone which represents the Seral conglomerate may be seen resting immediately upon a light olive and greenish-coloured shale, more or less arenaceous, and breaking into wedge-shaped fragments. These are the Sharon Measures. They contain two bands of sandy iron-ore easily wrought, and free from sulphur. They may be studied at the mouth of Paint Creek, one-third of a mile above the Clarion River Bridge.

Issuing from the base of the conglomerate, bog-ore is found E. of Shippensville, also in Elk Township, and in Beaver Township. A bog, one-third of a mile S.E. of the Lucinda Furnace, covers an acre of ground, and averages 3 feet in depth; while one of equal depth, a mile N. of the Furnace, covers from 2 to 3 acres.

At the county-seat of Clarion the Clarion Coal-bed lies 40 or 45 feet beneath the Court-house. It has been opened at its outcrop upon the face of the hill overlooking the Clarion River. The bed is 3 feet thick, but yields coal too impure for common use, because of the sulphur and pyrites which it contains. Attempts were made by Judge Myers to find the Brookville Bed, but they were not attended with success. The latter coal is said to have been penetrated by a well sunk many years ago on the high ground near the Court-house, at a distance of 30 or 40 feet below the upper coal. E. of the town the lower coal was bored into several feet; and it is highly probable that the same bed may be found of workable size at Clarion, after it has been fairly entered beneath the hill.

At Strattonville the series of rocks, as exhibited in Fig. 413, is the same that we have been considering. The fifth axis crosses the Brookville Turnpike about 3 miles W. of the Jefferson County line, and brings up the Tionesta Sandstone, dipping each way at an angle never exceeding two degrees. At Strattonville the upper beds of the Tionesta Sandstone are seen in the hollows crossed by the turnpike, while the trough of the Clarion River cuts down into the Vespertine sandstones.

Here the Brookville Coal is the principal bed, whereas to the W. and S.W. the Clarion Bed is the largest. The former is 4 feet thick (Fig. 413.) At Strattonville, 7 miles W. of Brookville, it is opened almost on the anticlinal axis, dipping only half a degree S.E., where it is 3 feet thick. At the bottom of a well, sunk through 30 feet of black and blue slates, there are large quantities of nodules of very fine carbonate of iron enclosed in shale. No limestone could be seen. These strata are above the Brookville Coal. Thirty feet above the mouth of the well was a clearly-defined coal-bench in the hill-side, probably the Kittanning Coal.

The ore said to be passed through 6 feet beneath the Ferriferous Limestone in Lowrie's Well at Strattonville, corresponds in position to that found beneath the same stratum at the Great Western Furnace on the Alleghany River, and elsewhere farther W. The Buhrstone ore and Ferriferous Limestone appear on the slopes of the hill around Wilson's opening in the Brookville Coal-bed, which dips 2° N.W., and is 4 feet thick. The very white and massive sandstone, seen for a thickness of 50 feet below the coal, is the Tionesta Sandstone: under it there are evidences of the presence of the Tionesta Coal-bed.

The diminution in the whole thickness of rocks between the Ferriferous Limestone and the Tionesta Sandstone in this neighbourhood, as well as the thinning-out of the Clarion Coal-bed, are worthy of remark. The section from Lowrie's Well is as follows—(see Fig. 413):—

Slate, 24 feet. Chert or Buhrstone, 2 feet. *Limestone,* 4 feet. Shale, with iron ore, 35 feet. *Coal* (*Brookville,*) 3 feet; Shale ore; Tionesta sandstone.

The hill-sides W. of Strattonville, sinking down to the Clarion water-level about 300 feet, give the following section:—

Kittanning Coal, thin (here first observed going S.W.) Interval, 80 feet. Limestone, 4 feet. Interval, 12 or 15 feet; *Clarion Coal,* 9 inches. Interval, from 15 to 20 feet.

Western Side of the Clarion.—The Tionesta Sandstone is the prominent cliff-rock in all the valleys that enter that of the Clarion upon its right bank.

At the Deal Bank, 2 miles S. of Shippensville, the Ferriferous Limestone-ore has been extensively wrought upon a flat-topped hill. The ore was from 6 to 4 feet thick, being exceedingly variable even in short distances. Over it lie about 6 feet of argillaceous slaty sandstone and shale bedded in a very irregular manner, and divided in several places by joints. Above this lies a brown shale. The ore is accompanied by chert, which occurs in pieces from 10 to 4 inches square, and appears to be most abundant in the upper part of the ore-bed. The limestone is separated from the base of the ore-bed by a greenish slaty sandstone several feet in thickness.

The Clarion Coal-Bed has been opened in this neighbourhood. It cannot be much more than 15 feet below the limestone. It is from 2½ to 3 feet thick. The *Brookville Coal* is upwards of 20 feet lower down, and is an inconsiderable bed. Both these coals have likewise been opened on the Deer Creek Hills, where they are 40 feet apart; the upper one 2 feet, and the lower one from 2 to 4 feet thick.

The Tionesta Coal is here seen, beneath the Tionesta Sandstone, 14 inches thick.—(See Fig. 413.)

The Kittanning Coal is supposed to exist in the high knobs 4 miles upon the Emlenton Road, S.W. of Berlin's Old Tavern, 4½ miles W. of Shippensville, with remnants of the arenaceous slate-group above it, and with 80 feet of strata below it to the Ferriferous Limestone. Proceeding into Elk Creek and Rockland townships, we see the Tionesta Sandstone still more abundantly in the hollows and ravines; and the Seral conglomerate is in the deep trench of Six-mile Run. A few of the most elevated knobs are capped by the limestone, and contain the underlying coal. The former is seen cropping out 2 miles E. of Myerstown on the turnpike at Six-mile Run, and also on another hill 2 miles toward the S.S.E. We find its line of outcrop marked by a series of small rounded hills, which pass nearly through the middle of Rockland Township. The outcrop of the Clarion Coal-bed conforms to that of the limestones above it. It enters only a few straggling knobs beyond this, towards the

N.W. That of the Brookville Coal is perhaps 2 miles still farther in the same direction. This bed is found only occasionally upon the Alleghany River above the mouth of Scull's Run—the upper beds not at all; but they all appear upon the hills where these become higher, half a mile or more back from the river.

Two miles below the mouth of Scull's Run the following section (see Fig. 416) was obtained:—

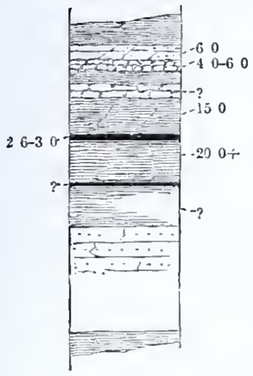


FIG. 414.—Deal's Bank, Shippensville.

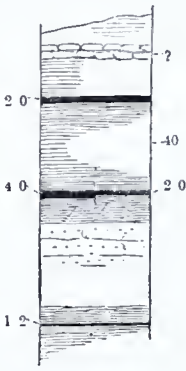


FIG. 415.—Deer Creek.

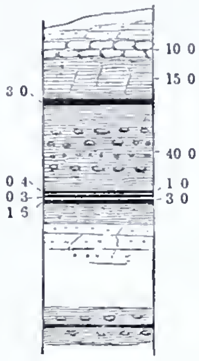


FIG. 416.—Scull's Run.

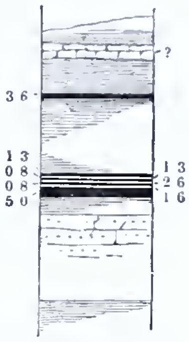


FIG. 417.—Rocklandtown.

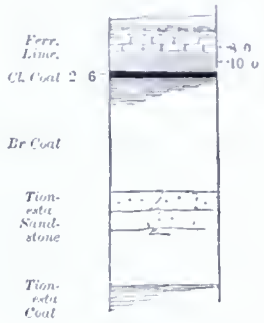


FIG. 418.—Alsboch's.

Sandstone, 8 feet exposed. *Ferriferous Limestone*, 10 feet. Interval, 15 to 20 feet. *Clarion Coal*, 3 feet; Brown Shale with iron ore, 40 feet. Brookville Coal, 4 inches; Black Slate, 1 foot; Coal, 3 inches; Black Slate, 3 feet; Coal, 18 inches; Black Slate; Slaty (Tionesta) Sandstone.

The four beds of nodular iron-ore in the 40-feet interval are in the descending order, according to the names by which they are locally known, as follows:—

1. "Roll Ore," in masses from 2 to 3 feet long, and from 8 to 12 inches thick, coarse-grained. 2. "Pig Ore," in cylindrical nodules, from 6 inches to 2 feet in length. 3. Small nodular band "Flag Ore," in flags from 6 to 20 inches in breadth, scaling off in conchoidal crusts upon exposure.

The presence of the *Tionesta Coal* is indicated along the river-hills by its outcrop smut; and the ore of this series is mined at Campbell's, and at the same height on the W. side of the river. The shale above and below the coal contains more or less ore.

Bog Iron Ore occurs on the lands of Messrs Rockwell & Co. in four places,—J. F. Retter; Boyne, J. Brown; Brigham estate, three places; Rockwell & Co., Pine Creek; Nichol's, Scull's Run; Smuller, half a mile E. of the furnace; and Thompson. Mr Smuller's bog-ore covers 10 acres, from 1 to 4 feet deep.

In *Richland Township* the bog-ore, issuing from the base of the Seral conglomerate, occurs on the lands of Messrs J. Shaeffer, J. Platt, Wm. Carn, and Wm. Knobs.

In the knolls upon Crawford's Farm the limestone is seen. Beneath it is the *Clarion Coal-bed*, 3½ feet thick. The *Brookville Bed*, though not exposed here, is seen 3 miles S. in a rather deep hollow, the alternations of shale and coal being as follows:—

Soil, 2 feet; *Coal*, 15 inches; Soft Black Shale, 15 inches; *Coal*, 8 inches; Shale, 30 inches; *Coal*, 8 inches; Hard Shale, 18 inches; *Coal*, 5 feet, which last has been opened by Mr Purviance, a mile distant.—(See Fig. 417.)

The limestone spreads itself very generally through the S. and S.E. parts of this township, and is accompanied in some places by the iron ore and buhrstone. The latter is found at J. Shaeffer's, Peter Bouch's, J. Alsboch's, &c. Five miles from Emlenton, and about 10 miles from Shippensville, all the strata in connection with the limestone are well exposed, thus:—

Soil, 1 foot; Clay, &c., 5 to 8 feet. *Ore*, from 10 to 18 inches. *Limestone*, with *Buhrstone*, 8 feet. Shale, brown, friable, 10 feet. *Clarion Coal*, 2½ feet (see Fig. 411.) The buhrstone is about 9 inches in thickness.

The Kittanning Coal-bed, 18 inches thick, is seen some distance above the limestone, near Foxburg, in the S. part of Richland Township, and on the high-land to the E. of Turkey Run, in Beaver Creek Township, and occasionally in the high land S. of the Clarion, and between the Alleghany River and Cherry Run. It is but a small bed, covered by shales, and these by the Freeport Sandstone (seen in the hills about Cherry Run and Licking Creek), and lies about 50 feet above the Ferriferous Limestone. This latter, having sunk down to near the base of the hills, is found abundantly in the ravines.

Both on the Alleghany and on the Clarion River in the neighbourhood of Callensburg, it is abundant, and only in the axis of the synclinal trough, about the head of Cherry Run, does it sink entirely below the level of the country. But at Curlsville, in the valley of Licking Creek, half-way between the Clarion and the mouth of Red Bank Creek, which is also in the middle portion of the trough, the limestone, with the buhrstone very finely developed, is seen in the low land.

On ascending the high hills three-fourths of a mile S.W. of Curlsville, on the Waterson's Ferry Road, we meet with the most N.E. localities of the *Lower Freeport Coal* (which belongs to the series next above), resting upon the Freeport Sandstone, and occupying the centre of the basin. It is opened both on the N. and S. sides of the road, the strata at the two places having dips in opposite directions, both towards the road which here runs in the middle line of the basin.

On the hill N.W. of the town four beds of coal have been opened: first, high on the hill, the Lower Freeport Bed, approaching its final outcrop; next, the Kittanning Coal, underlaid at some distance by the Ferriferous Limestone, which forms a conspicuous bench; and immediately beneath this a thin coal-seam, and at the base of the hill the Clarion Coal-bed well developed. These beds are of workable dimensions.

Its N. line of outcrop extends in a pretty regular line to a point on the Alleghany River, two and a half miles below the mouth of Beaver Creek, while its S. line of outcrop passes about three-fourths of a mile S. of Roseburg towards the mouth of Red Bank Creek. The area, therefore, occupied by this seam on the E. side of the Alleghany is not great, its greatest width being little more than six and a half miles. The Lower Freeport Coal-bed has been opened in several places, and yields from 2 to 4 feet of tolerably good coal.

The *Upper Freeport Coal*, supported by the Freeport Limestone, and at an elevation in the series of 40 feet above the Lower Freeport Coal, is first met with on a high knob to the N. of the Roseburg Road, half a mile from Curlsville. The *limestone*, as seen in fragments, is a light-blue compact rock, weathering yellow, because containing some peroxide of iron. The coal lies a few feet above it. One outcrop runs in a North-bending curve to the Alleghany, two and a half miles above the mouth of Catfish Creek; the other passes half a mile N. of the Roseburg Road to the Waterson's Ferry Road, three and a half miles from the river, where a high hill, over which the road passes, contains coal and limestone, and skirts the river opposite Dennistoun's Run.

The Upper Freeport Bed yields from 3 to 4½ feet of good coal. The Ferriferous Limestone usually measures 4 feet. It yields a good lime, but is little used. It rests on 15 or 20 feet of arenaceous shale, containing near the bottom from 8 to 14 inches of nodular iron-ore in a single band, easy to smelt, and more profitable to work than many richer but harder ores. It is opened on the W. side of the river.

The River-hill Slopes at the centre of the basin are from 400 to 500 feet in height.

On its S.E. outcrop, in the Sixth Basin, the Kittanning Coal-bed becomes of available thickness only on approaching the Alleghany River, in the neighbourhood of Lawrenceburg and Sugar Creek, around Curlsville and Roseburg. In Madison Township, as opened by Messrs J. Weaver and P. Kratzer, it is 3½ feet thick. Here the Ferriferous Limestone and its ore occur, and again at the mouth of the Red Bank, and it is opened on the anticlinal axis. The lower coal-beds appear in the ravines, entering the Red Bank near its mouth.

CHAPTER XVI.

SIXTH BASIN; SOUTH-EAST-DIPPING CLARION GROUP; REGION WEST OF THE ALLEGHANY RIVER.

THE country to be described lies between a line drawn from the mouth of the Scrubgrass Creek on the Alleghany, through the S.W. corner of Sandy Lake Township, Mercer County, to the forks of the Mahoning

River at Newcastle, and another line drawn from the centre of Parker Township, Butler County, to the Beaver River above the mouth of the Conequenessing Creek.

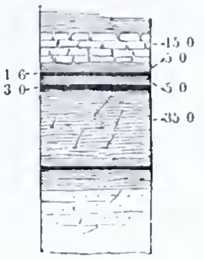


Fig. 419.—Scrubgrass Creek.

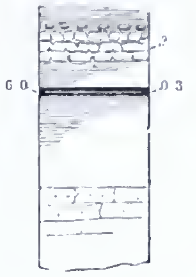


Fig. 420.—Mercer, Sandy Lake.

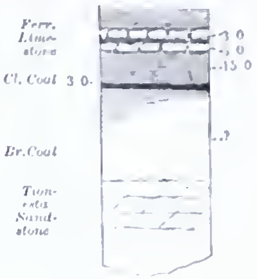


Fig. 421.—Sandy Lake.

The Brookville Coal, outcropping along the former of these boundaries, is poorly represented on this side of the river, in the neighbourhood of Scrubgrass Creek (see Fig. 419). It is usually about 18 inches thick, and separated from the Tionesta Sandstone by from 1 to 10 feet of brown shales. Above it is shale, usually brown, from 30 to 40 feet thick, which is the chief repository of the nodular iron-ore found in the Northern townships of Butler County, and the townships of Scrubgrass and Irvin in Venango County, if we except that found beneath the Tionesta Sandstone.

The *Clarion Coal-bed* rests upon this shale, and is from 10 to 20 feet below the Ferriferous Limestone. These two seams of coal and the limestone outcrop very closely to each other, in a line passing directly E. and W. from the head of the run that empties into Scrubgrass Creek, one-fourth of a mile above its confluence with the Alleghany, to the S.W. corner of Sandy Lake Township, and the adjoining corner of Springfield Township, about a mile to the S.W. of the former. Thus far the outcrop of the next underlying coal accompanies that of the limestone very closely; but the Brookville Bed, though it probably exists, was not met with in the neighbourhood of the latter, unless perhaps at Brackenridge's and at Ossick's Mill; but these openings are supposed to be upon the *Clarion* Bed. Ossick's Bank is a few hundred feet to the N. of the Franklin and Mercer Road, and is not now open. The bed is said to be thin. A short distance farther down the creek, the upper layers of the Tionesta Sandstone are seen ; it is quarried 2½ miles S. of the mill.

The whole of this line of outcrop is marked by a number of small rounded knolls, some of which are capped by the limestone bed *in situ* ; others afford merely a few fragments under the ploughshare upon their summits. In the neighbourhood of Venango Furnace, and in the hills about Scrubgrass Creek, we find, in the shale embraced between the Tionesta Sandstone and the Seral conglomerate, the small Tionesta Coal, from 12 to 18 inches thick. In the shale above the coal occurs a seam of not very good coarse-grained bluish iron-ore, a very easy ore to work, and said to be a profitable band. It lies in two or three layers of nodules, varying from 15 inches in diameter to the size of a hen's egg. This ore has been opened in several localities, and was before noticed on the E. side of the Alleghany River. It is easily recognised, as no other bed has been discovered between the two heavy sandstones in the vicinity of the Alleghany. At the base of the conglomerate, bog-ore is found in several places along Scrubgrass Creek, on the run which empties into it, one-fourth of a mile above its mouth, and at Cross's furnaces.

The Tionesta Sandstone, with the upper part of the conglomerate, is seen in the deep hollow of Scrubgrass Creek, on the road from Franklin to Warrensville. The strata resting upon the upper of these two heavy beds are well seen in the adjacent hills. The following short section was taken one-third of a mile S. of the Creek :—

Ferriferous Limestone ; Shale, 5 feet ; Bituminous Shale and Coal, 1½ feet ; Shaly Sandstone, 5 feet ; *Clarion Coal*, 3 feet ; Bluish Shale, 35 feet ; Black Slate ; *Brookville Coal*, 18 inches ; Shale, 5 feet ; Tionesta Sandstone.

The limestone is found in the immediate vicinity, and where the whole stratum exists is about 15 feet thick, of a blue colour, and *unaccompanied by the buhrstone and its ore.* We here for the first time meet with an interposed seam of coal between the limestone and the Clarion Bed. It is never more than 20 inches thick, is slaty, and frequently immediately underlies the limestone. It may perhaps be considered as an upper member of the Clarion Coal, subdivided by the intercalation of slate.

The *Brookville Coal* in Venango County and Northern Butler is only on an average 18 inches thick, and is but a few feet above the Tionesta Sandstone.

At Messrs Johne's and Bradley's, in Sandy Lake Township, Mercer County, the limestone consists of two distinct strata, separated by a band of calcareous clay, with a seam of coal. The upper portion is a light-grey compact bed, about 3 feet thick. The clay is bluish, with a seam of coal from 1 to 6 inches thick, the whole being from 12 to 15 inches in thickness. The lower portion of the limestone is blue, earthy, less compact than that above, and only sparingly fossiliferous: 4 feet of it are exposed, but it is said to be 6 feet thick.

Three-quarters of a mile S.W., the Clarion Coal is seen 15 or 20 feet below the limestone: it is 3 feet thick, and overlaid by shale. The Scrubgrass Seam was not detected here, and has probably thinned out. These two beds of coal, with the limestone which overlies them, occur in isolated patches over the greater part of Scrubgrass and Irvin townships in Venango County, and a large part of Wolf Creek Township in Mercer County. In the N. part of Butler this limestone is abundantly met with, but is usually destitute of iron ore and chert. In the N. townships of Butler County it begins to occupy a lower position in the hills, and the Kittanning Bed is found near the summits of some of the most elevated. It is hardly possible to trace the irregular outcrop of this seam, but in general it very nearly follows a line parallel to the county-line between Butler and Venango, but about 1½ miles farther N. to the White Oak Spring, and thence to the Pittsburg and Erie Turnpike, at the S.E. corner of Springfield Township.

The *Clarion Coal-bed* is mined in several places in the N. part of Butler County, until it assumes so low a relation to the water-level as to be inaccessible. It is mined at Mr Leonard's, where it affords an excellent fuel; and in the neighbourhood of Lawrenceburg, in Mercer Township, at Mr Criswell's, and 2½ miles to the N.E., where it is 6 feet thick. It here lies near the base of the hill, and yields a very excellent solid coal, parted by about 3 inches of slate. The Ferriferous Limestone is very generally met with through the whole of this part of Butler County, sometimes accompanied with the chert, but usually destitute of the iron ore. The latter is observed as we approach Centreville, and 4 miles E. of that village it is from 6 to 20 inches thick. Sometimes it is almost wholly replaced by the buhrstone, which is often a foot in thickness, and rests immediately upon the limestone. At Buchanan's, 2 miles from the village, the ore and buhrstone average together about 8 inches in thickness, and are often separated from the limestone by as many inches of clay: the buhrstone is not, however, abundant; it is of a greyish or cream colour, and has a cellular structure.

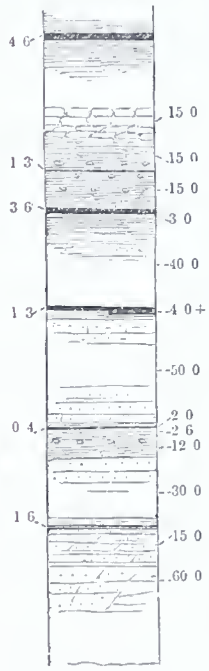


Fig. 422.—Lawrenceburg.

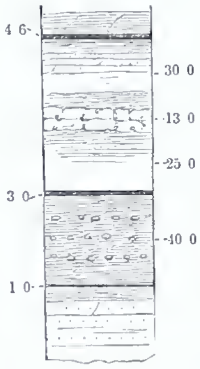


Fig. 423.—Slippery-Rock Creek.

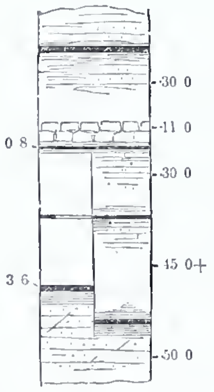


Fig. 424.—Beaver River, Newcastle Turnpike.

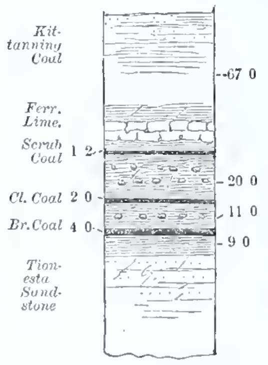


Fig. 425.—Neshannon Little Branch.

At a higher level we observe the Kittanning Coal-bed: it has been opened 2 miles S. of Harrisville; is rather shaly, but burns well; is from 4 to 4½ feet thick, and usually covered by slate. The Freeport Sandstone is frequently seen at the tops of the hills containing it.

It extends through Venango Township, and has been opened near Lawrenceburg, but is not so profitable a bed as the Clarion Coal below the limestone. In the middle district of the township the seam is sufficiently thick, but the coal is slaty and impure.

The following section was compiled in the vicinity of Lawrenceburg—(See Fig. 422):—Olive and Brown Slate; Ferriferous Limestone (chert), 15 feet; Shale, 15 feet; *Scrubgrass Coal*, 15 inches; Brown Shale (ore), 15 feet; *Clarion Coal*, 3½ feet; Fire-clay, 3 feet; Sandstone, more or less slaty, 40 feet; *Brookville Coal*, 1¼ (4?) feet; Tionesta Sandstone, 50 feet; *Black Slate*, 2-feet *coal* (Tionesta Bed), 4 inches; Fire-clay, 2½-feet shale, with one band of iron ore, 12 feet; Sandstone, 30 feet; *Bituminous Shale*, 2½ feet; Slaty Sandstone, 15 feet; *Fire-clay*, with vegetable remains, 15 inches; Sandstone, sometimes massive, 60 feet.

The Kittanning Coal-vein is found on the hills farther back from the river. The fire-clay underneath the Clarion Coal is good, and has been taken to Pittsburg. The thickness of the Brookville Bed is not known with precision: in one place it was ascertained to be but 15 inches; but a 4-feet seam S. of Lawrenceburg is supposed to be the same, although it may possibly be the Clarion Bed.

One mile above Lawrenceburg, opposite the mouth of the Clarion River, the Ferriferous Limestone occupies the highest hills in massive ledges upon Mr Robeson's land. It is underlaid by slate or shale, 15 feet thick, descending to a small seam of coal not exceeding 18 inches in thickness. About 15 feet beneath the latter the main bed of the district (Clarion Coal) is opened. Its thickness varies from 3 feet 6 inches to 5 feet, averaging 3 or 4 feet of good coal. Several thin bands of slate containing pyrites are interstratified with the coal. Some distance below this bed a small seam, perhaps 6 or 12 inches in thickness, appears to represent the Brookville Coal. The bed is slaty and valueless. In the shales associated with this seam, iron ore has been found; several hundred tons have been carried to Kensington Furnace, opposite Emlenton. The ore has not proved abundant, and is difficult to smelt.

Tracing the several beds W., we can perceive them subject to very little variation, unless it be in the thickness of the strata between the coals. A depression in the general surface of the country in Wolf Creek Township prevents the limestone from outcropping in as regular a line as it does in Venango County. It is seen near the base of a high knob on the Old Pittsburg Road, 7 or 8 miles S. of Mercertown, as a light-blue limestone, 15 feet thick. A short distance below it is the *Clarion Coal*, which is not opened in this immediate vicinity, but its position is well marked. The *Brookville Coal-bed* is seen near the top of a hill 2 miles farther N. at Springfield Furnace, being separated by only a few feet from the top of the Tionesta stratum, 60 feet thick, and well exposed within a few rods of the Falls. From this place we follow the outcrop of the limestone in a direct line to the mouth of the Little Neshannock, and thence to Newcastle, on the W. side of the Great Neshannock Creek, where but a few points of land are sufficiently high to take it in their summits. In the vicinity of the Shenango, and in all the E. half of Mahoning Township, the general level of the country falls off a little, and does not reach the limestone stratum even at its highest points, with the exception of the high ridge which runs down from the N.W. to the Mahoning, between Youngstown and New Bedford. At the lower end of this ridge, where the Newcastle and Poland Road crosses it, the Ferriferous Limestone is again seen. This, with the exception of a small outlying patch S.E. of New Bedford, is the last knob capped by the Ferriferous Limestone towards the N.W. The surface of the country declines to a lower level N. along the line of this outcrop of Ferriferous Limestone, which served as a partial protection to the underlying coals and their including shales against the general denudation. Their outcrops, therefore, correspond geographically with its own. The lower lever is that of the Tionesta Sandstone, which overspreads the greater part of Lackawanna Township.—(See Fig. 426.)

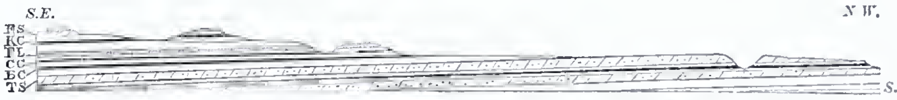


FIG. 426.—Lower Coal-measures, N.W. Corner of Lawrence County.

The country for some miles S. of this line is well supplied both with coal and limestone. The smallness of the angle at which the beds dip towards the centre of the basin makes them accessible over a wide area. This condition of things gives great advantages to the farming region of this basin over the country traversed by the several axes farther to the E. It will be needless to specify the very numerous localities at which the limestone and the two underlying coal-beds occur in their broad range through the townships of Wolf Creek, Slippery Rock, and the S.E. part of Neshannock in Mercer County, Slippery Rock and Muddy Creek townships in Butler County, and Shenango, North Sewickly, North Beaver, Little and Big Beaver townships in Beaver County; but in connection with the overlying strata we shall have frequent occasion to refer to these. Over this area, with the exception of Wolf Creek Township and the neighbourhood of Centreville, neither the chert nor the iron ore is seen in connection with the Ferriferous Limestone. At the bridge over Slippery Rock Creek, on the Butler and Mercer Turnpike (see Fig. 423), we have at the water-level the Tionesta Sandstone; a few feet of brown shale separate it from the Brookville Coal-bed, here a mixture of bituminous shale and coal 12 inches thick. Above this rests the great repository of the oolitic iron-ore, usually a brown or yellowish shale, sometimes an argillaceous sandstone, in which case the iron ore is in less abundance. The whole stratum is here about 40 feet thick. Upon this rests the *Clarion Coal*, 3 feet thick; 25 feet of shale and slaty sandstone separate this from the Ferriferous Limestone, which is from 12 to 14 feet in thickness, of a bluish colour, and tolerably compact. In the neighbourhood of this locality, the Kittanning Coal is repeatedly seen from 3 to 4 feet thick, and covered by a heavy bed of brown shale, containing some argillaceous shaly sandstone, and occasionally a considerable quantity of nodular iron-ore. This ore was formerly mined for an old furnace on Slippery Rock Creek. Approaching Newcastle, the limestone is abundantly found, as was before stated, being there nearly at its outcrop. The Kittanning Coal is likewise found E. of the town, and S. of the Neshannock, and is from 19 to 32 feet above the limestone. At Ray's, a small bed of coal (Scrubgrass Coal) is found immediately below the limestone; and 22 feet above it is the Kittanning Bed, 3½ feet thick, capping the very highest points of land. The right-hand portion of the column represents the following Section made at Newcastle (for its continuation to water-level, see Fig. 424) :—

Flaggy Sandstone. *Kittanning Coal*, 3½ feet; Fire-clay, 2 feet; Shale and Sandstone, 30 feet; *Ferriferous Limestone*, 11 feet; *Scrubgrass Coal*, 8 inches; Fire-clay; Shaly micaceous Sandstone and brown shale, 30 feet; *Clarion Coal*, 2½ feet; Fire-clay; Argillaceous sandstone, 45 feet, or more; *Brookville Coal*; Brown Shale; Tionesta Sandstone.

The *Clarion Coal Vein* is worked at Henkson's and Ray's, and elsewhere: it is usually overlaid by shale holding a few scattered nodules of argillaceous iron-ore, and underlaid by brown shale and argillaceous sandstone. On a small stream, which empties into the Neshannock on the S. side, the following section (see Fig. 425) was obtained :—

Limestone; Shale, a few feet; *Scrubgrass Coal*, 14 inches; Shale with ore, 18 to 20 feet; *Clarion Coal*, 2 feet; Shale with ore, 11 feet; *Brookville Coal*, 4 feet; Brown Shale, 9 feet; Tionesta Sandstone.

The farm of Dr Whippo is the nearest locality to Newcastle, where the limestone is found; it is there well exposed: also on the road to Butler, about 1½ miles from town, its fragments are strewed over the high ground over which the Newcastle and Conequenessing Road passes, 1½ or 2 miles from town.

The *Brookville Coal-bed* is opened on Dr Whippo's farm, and is 61 feet below the base of the limestone, and 3½ thick, yielding a sort of cannel coal, and mining with a cubic fracture.

The distance of the *Kittanning Coal* above the Ferriferous Limestone increases Southward toward the mouth of the Beaver River, while the two lower coals diminish in size in the same direction. The strata dip gently S., bringing the limestone, which at Dr Whippo's, near Newcastle, stands 300 feet above the Neshannock water-level, down to 42 feet above the Beaver River water-level at Whampoa Hill, 3 miles above the mouth of the Conequenessing. Allowing for the fall of water, 235 feet is left for the amount of dip in that distance.

At Whampoa Hill the Kittanning Coal-bed is separated from the limestone by 67 feet of strata, this increase in the distance being occasioned by the great augmentation of silicious layers which occupy the intervening space. Above it rest many feet of flaggy sandstone and shales, which are here the representatives of the Freeport Sandstone, and the shale and slate which underlie it. The Kittanning Coal-bed on the W. side of the Beaver River outcrops on the high land S. of Hickory Creek.

CHAPTER XVII.

SIXTH BASIN WEST OF THE ALLEGHANY RIVER—FREEPORT GROUP.

THE N.W. outcrop of the *Lower Freeport Coal-bed* crosses the Alleghany River in the hill-tops, a mile above Miller's Eddy, and the Butler and Little Scrubgrass Creek Road, and about 2½ miles S. of the N. line of Parker Township, or 6 miles S.W. of Lawrenceburg. Here it bends, and runs in a straight line to the Mercer Turnpike, 12 miles from Butler, and 1½ S. of the Stone Tavern, and onwards to Slippery Rock Creek, 3 or 4 miles above its confluence with the Conequenessing, crossing Beaver River, 3 miles above the mouth of the Conequenessing, where it is a fine bed, 6 feet thick.

Its line of outcrop then passes S. of Whampoa Hill in an undulating course, through Big and Little Beaver townships, and 3 miles to the N. of Greensburg to Fairfield in Ohio.

The S. line of outcrop of this bed, running S. of Curlsville, past Roseburg, to the Alleghany River, at the mouth of Red Bank Creek, after crossing the river follows a S.W. course, but gradually approaches the line of the fifth anticlinal axis, and at length arches over it at the forks of Buffalo Creek, 2 miles above the Butler and Kittanning Turnpike, on the W. side of the Creek.

Outside of the limits of the area included between these lines, the Freeport Coals are nowhere seen. Along its limits runs the Freeport Sandstone, which supports the series towards the E. It is a well-characterised, soft, yellowish, clear-grained sandstone, disposed to massiveness, but sometimes slaty; towards the W. running into silicious slates and thinly-bedded sandstones. It is usually about 50 feet thick, and overlies a very irregular group of soft argillaceous shales, which furnish the variable element in the unequal interval between the Kittanning and Lower Freeport Coal-beds. A great variation of interval is produced also by unequal denudation acting upon these same lower and softer rocks.

The Upper Freeport Coal, it was before stated, is separated from the lower bed by slate and slaty sandstones usually about 40 feet in thickness, and of course occupies a similar but smaller geographical area; its regular line of outcrop is usually from 2 to 3 miles distant from the former. From the Alleghany River Hills, about 2 miles above the mouth of Catfish Creek, it ranges W. in an undulating line across the road from Bear Creek Furnace to Fairview, within a mile of the latter place; thence N.W. to a knob high on the Butler and Little Scrubgrass Road, S. of the Six Cross Roads in Parker Township. Bending again like the outcrop of the Lower Freeport Bed, it proceeds directly to the Mercer Turnpike, 2 miles N. of Unionville. In this neighbourhood, however, it is not very easily traced, but traversing the high and little-broken country to the W., it strikes the Conequenessing 4 or 5 miles below the mouth of Slippery Rock Creek and the Beaver River, about 3 miles above Old Brighton Bridge. From the Beaver River it pursues a N.W. course to the Church, one third of a mile N. of Greensburg, and thence runs W. into the State of Ohio towards New Lisbon.

This line marks the N. outcrop of the Upper Freeport Bed, while the Freeport Limestone which underlies it extends its own outcrop only in a few instances beyond that of the coal.

The S.E. outcrop in this basin may be described by a tolerably straight line drawn from the hill N. of the mouth of Red Bank Creek to the Butler County line, where it is crossed by the Buffalo Creek N. of the Kittanning Turnpike; and thence to the back of the axis, 2 miles N.E. of Hannastown.

As the medial line of the Sixth Basin crosses the Alleghany River below the mouth of Sugar Creek, the hill-slopes, upon which the harder rocks stand out in picturesque cliffs, afford admirable exhibitions of the rocks from as low down as the upper layers of the Seral conglomerate in the bed of the river, to almost the uppermost strata of the Freeport series. This the following section (Fig. 427) will show:—

Sugar Creek Section, Great Western Furnace.—Shale and Slate, 60 + feet. *Upper Freeport Coal,* 4 feet 6 inches (at the Summit Coke-yard the bed is 6 feet thick); Fire-clay and Shale, with beds of nodular iron-ore 2 inches thick, 7 feet 6 inches. *Freeport Limestone,* 5 feet; Fire-clay, 18 feet. *Calcareous Ore,* "Summit Bed," 2 to 2 feet 6 inches; Fire-clay, 20 inches; Sandstone, 30 feet. *Lower Freeport Coal,* 15 inches (in Phillips' Hill, 4 feet); Shale, passing downwards into slaty thin flaggy sandstone (Freeport S.), 65 feet. *Coal,* 10 inches; Fire-clay, 2 feet; Sandstone more or less massive, including a thin band of worthless silicious ore, 62 feet. *Kittanning Coal,* 3 to 4 feet; Fire-clay, 4 feet; Shales, olive and blue, including a stratum of bituminous shale, which locally becomes cannel coal, 5 feet thick; Argillaceous Sandstone and concretionary iron-ore, 40 feet. *Silicious Iron-Ore,* "Slab Vein," 20 inches; Sandy Shale, 12 feet. *Ferriferous Limestone,* 15 feet. *Ore,* 4 to 10 inches. Shale, blue and slaty sandstone, 40 feet. *Clarion Coal,* 2 feet; Fire-clay, 2 feet; Shale and Sandstone, 30 feet. *Bituminous Shale,* 0; Shale, 25 feet. *Bituminous Shale and Coal,* 12 to 18 inches. White Sandstone (Tionesta), 60 feet; Bituminous Shale interlaid with sandstone, 20 feet. Seral conglomerate.

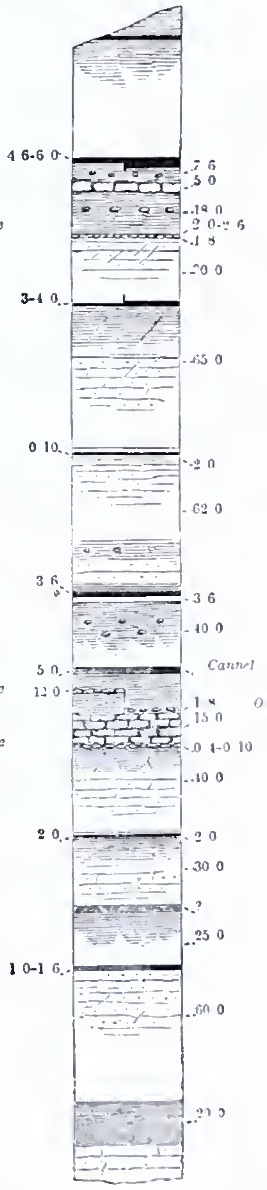


FIG. 427.—Great Western Furnace, Sugar Creek.

The bed of coal wrought for coking at the Great Western Furnace is the Upper Freeport Coal, which is found the best. The Kittanning Coal-seam supplies the rolling-mills with fuel, and is wrought to a limited extent for furnace use.

The iron ore constituting the main dependence of the furnaces is the calcareous ore underlying the Freeport Limestone known as the "Summit Vein." Though it averages not more than 2 feet or 2 feet 6 inches in thickness, it has been found, in the Phillips' Hill, 4 feet thick. The ore yields 30 per cent metal in the furnace. The stratum of fire-clay over the ore is used for making fire-brick, for which it is admirably adapted. Before its discovery, that beneath the Kittanning Coal was used. The "Slab Vein" of ore fluctuates both in character and distance from the limestone beneath. When separated from the limestone by sandy shale, it is a silicious buhrstone ore, but, approaching the limestone, it becomes more calcareous and scaly. In some places it is highly impregnated with bituminous matter and sulphur. Its dimensions are quite uniform. The average yield of the ore in metal is from 35 to 37 per cent.

The Elk Lick Coal-bed here makes its appearance on the highest ground back from the river as the largest bed in the section: it is 50 feet above the Upper Freeport Coal, and is fully 5 feet thick. We shall hereafter notice it again at Alleghany Furnace.

The small interpolated bed beneath the Freeport Sandstone is said to be found farther W. on the lands of the Brady's Bend Coal and Oil Company, much increased in thickness, and in the form of *cannel coal.* The bed is reported by Professor Owen to be from 2 feet 6 inches to 3 feet 10 inches in thickness. The specimens from the seam indicate a light compact cannel-coal, having a conchoidal fracture. It is proposed to extract lubricating and illuminating oils from it.

Some beds of the thick sandstone stratum near the base of our Sugar Creek section are formed of pure white sandstone, suitable for glass-making. Large quantities of the rock have been shipped to Pittsburg for that purpose.

The Great Western Iron Furnaces are situated on Sugar Creek, 2 miles above its mouth. There are four stacks for the smelting of iron, of which two are 50 feet high, 14 feet across the boshes, and 7 feet diameter at the trundle-head; and two 45 feet high, 11 feet bosh, and 6 feet at the trundle-head. They all employ hot-blast. Connected with these, an extensive rolling-mill at the mouth of the creek moulds the iron into the form required.

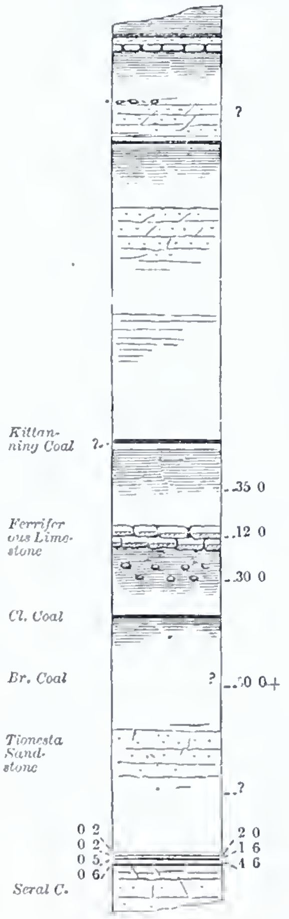


FIG. 428.—Alleghany River, 7 miles above Sugar Creek.

Fig. 428 represents a section made upon the Alleghany River at Miller's Eddy, 7 miles above the mouth of Sugar Creek; it reads as follows:—

Upper Freeport Coal, roof, shale; floor, fire-clay, 3 feet thick. *Freeport Limestone,* 0; Shale and shaly Sandstone, 40 feet. *Lower Freeport Coal,* small, interval 135 feet, in which occurs the contorted Freeport Sandstone. *Kittanning Coal;* Shale, 35 feet. *Ferriferous Limestone,* 12 feet; Shale, with nodules of argillaceous ore, 30 feet. *Coal,* and interval, 50 feet. Tionesta Sandstone. *Coal,* 2 inches; Shale, 2 feet; *Coal,* 2 inches; Argillaceous Sandstone, 18 inches; *Shaly Coal,* 5 inches; Argillaceous Sandstone, 4½ feet; *Coal,* 6 inches; Seral conglomerate.

This section is not more than 4 miles distant in a straight line from the last.

The Upper Freeport Coal and the underlying limestone here make their final N. outcrop.

Leaving the river and going W. we find the two Freeport Coal-beds frequently opened within their respective areas, but more frequently the upper one, which is usually the thickest, and affords the purest coal. In the neighbourhood of Fairview it is extensively mined.

The Elk Lick Coal occasionally appears, but nowhere as a workable bed, along the central line of the basin.

At Butler the Freeport Sandstone is seen along the valley-sides of the Connequenessing Creek. The Catholic Church is built upon it, and partly of stone quarried from it. The stone is considered to be, for building purposes, the best in the neighbourhood. The whole stratum is here about 50 feet thick.

The *Lower Freeport Coal* may be found at or near the water-level of the Conequenessing. It has been dug into at various points, but has never been fairly proved. On the land of Mr Boyd, a short distance E. of the town, a coal-bed near the creek-level was opened: it is said to be 2 feet thick, and of the cannel variety. This is a condition in which this seam is frequently found.

The *Upper Freeport Coal* passes through the town at about the level of the pavement of Zimmerman's (formerly Hamilton's) Brick Tavern, and was cut in digging for the foundations of the New Court-house. It has been extensively wrought by Messrs Neighley, M'Laughlin, Bradin, Shäffner, and others. At Shäffner's (formerly Bradin's) Bank, 1 mile S. of the town, the bed is 4 feet thick, the upper 12 or 18 inches of it being sometimes cannel coal.

Upon the Old Pittsburg Turnpike several drifts have been opened upon the bed, and it yields in all of them its usual thickness of 4½ feet of good coal. Small faults or dislocations have been developed in this vicinity; and fissures occur in the bed from a few inches to 3 or 4 feet in width: these are usually filled up with clay; the faults are sometimes, but not always, downthrows. Where a gangway is driven past a fault, the drainage of the land above will cause its abandonment. If the dislocation be so great as to make it troublesome to find the bed upon the farther side of the fault, it is considered more profitable to abandon the drift, and begin another from the outcrop.

The Elk Lick Coal may be seen high on the Plank Road Hill, S., and on the turnpike N. of the town, near the Cemetery. Its thickness varies from 9 to 15 inches.

The Freeport Limestone occurs in the form of nodules, imbedded in a white or grey calcareous clay, containing minute fossils exceedingly difficult to collect uninjured. It appears at several drifts on the Old Pittsburg Turnpike, and within a mile or two E. of the town; also in the street descending W. from the Court-house.

Above the thin Elk Lick Coal-bed, in this neighbourhood, is a stratum exactly resembling the variegated shale seen at the turnpike-gate near Kittanning, on the Indiana Road. In it are frequently found small calcareous ferruginous nodules, while the shale itself, especially the blue variety, contains a slight intermixture of calcareous matter. Its thickness is unknown, but it must be considerable. It is probably that member of the Barren Measures which is seen at the mouth of Sawmill Run, and at other points along the base of the hills at Pittsburg. The upper half of many of the hills for 3 miles N., and 4 miles E. of Butler, consists of these variegated shales; but as we approach the fifth anticlinal axis 4 miles E. of Woodville, the sandstone and slate which overlie the upper Freeport Coal-bed shut them out from the tops of the hills. This axis, after passing Hannastown, is little more than a broad gentle undulation in the strata, rapidly dying out S.W. The variegated shales appear beyond it to the S.E., in the neighbourhood of Pughstown, near the county-line, and 7 miles from Freeport. A thin sandy ferruginous blue or brown limestone, abounding in fossils, overlies the last-mentioned shale stratum. This limestone has a wide range, being found on the Little Mahoning, on the highest hills near Kittanning and S. of the Kiskiminetas. Beneath it, and separating it from the shale, is a seam of hard brilliant coal, varying in thickness from a few inches to 1½ feet, but by no means constant, having been noticed in the present district in only a few instances: it is wanting at Kittanning and at Little Mahoning. It is usually from 6 to 8 inches in thickness. The limestone is found in most of the hills immediately around Woodville, and may be seen in the bank of the Butler Turnpike, about half a mile from the bridge, and probably 40 or 50 feet from the top of the hill. As the basin deepens towards the S., it occupies a wider area, and is found lower in the hills. It is from 1 to 2 feet in thickness, covered by olive or blue slate (see Fig. 429). Four and a half miles from Woodville, the upper *Freeport Coal-bed* is seen a few feet above the water of Glade River. It is here, as at Butler, overlaid by brown shale; sandstone occupies the upper part of the hill. The seam is here about 2 feet thick, and yields a good coal. The Freeport Limestone is seen in the bed of the creek.

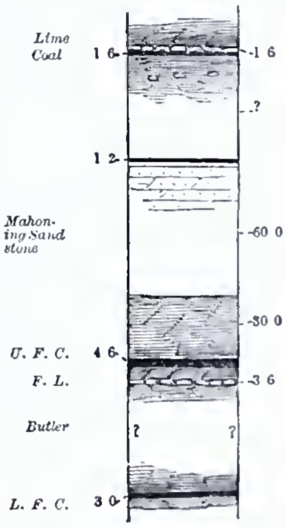


Fig. 429.—Zelienople and Harmony.

The description given of the strata around the town of Butler applies to the surrounding country.

Between Butler and Harmony few exposures are seen; the banks of the Conequenessing slope gently, and are covered with detritus concealing the strata. At Harmony and at Zelienople the lower Freeport Coal has been opened in several places. It rests here on blue shale, and is about 5 or 6 feet above the creek at the mill, half a mile W. of Harmony. It is from 2½ to 3½ feet thick, and frequently contains sulphuret of iron. The shale beneath it, which is blue or brown, and here represents the upper part of the contorted sandstone, contains a few scattered nodules of argillaceous iron-ore. Above the coal is shale and argillaceous sandstone, some portion of the former being slightly bituminous, and containing a few marine organic remains. The upper Freeport Coal-bed is poorly developed, but is found, together with its limestone, in the hill opposite Zelienople.—(See Fig. 429).

Five or six miles S. of Harmony, the variegated calcareous shales of the Barren Measures again appear, as described in the neighbourhood of Woodville or the Glade Mills. The shale here outcrops in the tops of the hills as through the middle and northern portions of Economy Township, and northern portions of Hopewell Township, on the opposite side of the Ohio River. The black fossiliferous limestone is found occupying its usual portion a little farther S., and is occasionally accompanied by the thin underlying coal-vein.

At Burns's Tavern, near the county-line, upwards of 10 miles S. of Harmony, a greenish non-fossiliferous limestone, rather impure, and breaking into rhombic or cubic pieces, is seen in connection with much red soil. Its thickness is about 3 feet, but it is too impure to be employed at the kilns. This is the second bed of limestone above the waters of the Ohio at Pittsburg, and will be more particularly described along the Kiskiminetas.

All the hills between Conequenessing Creek and the Beaver River, from a mile or two below the mouth of Brush Creek to the Harmony and Beaver Road, are occupied by the Barren Measures. In the hollows, however, especially towards the mouth of Brush Creek, the Upper and Lower Freeport coals crop out, both of them being exceedingly irregular in thickness. Not unfrequently the upper seam is reduced to only a few inches, or wholly absent; and then again, within a fourth of a mile, it may be a workable bed. These sudden changes in thickness are characteristic of this coal, as we shall see in tracing it through Westmoreland County. The brown shale which, at Sugar Creek and Butler, was seen resting upon the coal, is here frequently replaced by flaggy sandstone, forming the roof of the bed, which is generally thin. The limestone below it is remarkably constant in its attendance upon the coal.

CHAPTER XVIII.

FREEPORT GROUP, SIXTH BASIN, AND COUNTRY WEST OF THE BEAVER RIVER.

In the hills of the Beaver River there are fine exposures of all the rocks, from the middle of the Barren Measures down to the Tionesta Sandstone. Sections of the lower rocks at Newcastle, &c. have already been given; but as we descend the stream, these sink one by one below its bed, until the massive stratum of the Ferriferous Limestone is seen half out of water in the Ohio River banks, at the mouth of Ten-mile Run (see Fig. 433). The massive sandstones of the country to the N.E. and E. are here represented by far softer rocks, slates, and shales; and the relative distances of the beds from one another are also different. The approximation of the Kittanning and Lower Freeport coals, for instance, is very striking. The Ferriferous Coal seems to be entirely wanting. The Freeport group is greatly enlarged, while the Ferriferous Limestone swells to a size even beyond that which characterises it upon the Alleghany at Kittanning.

The following section (Fig. 430) was taken in Trough Run above the upper bridge, on the E. side of the Beaver River, and nearly opposite the Old Brighton Iron-works. The upper layers of the Tionesta Sandstone may be seen approaching the water-level of the Beaver at the bridge, and form part of the falls at Patterson's Dam, between Falston and Old Brighton Bridge:—

Sandstone, flaggy, 60 feet; Coarse brown Shale, 7 feet. *U. F. Coal*, 1½ feet; Clay and Shale, 4 feet.

F. Limestone, rather nodular, 3 feet; Blue and brown Shale, 37½ feet. Slaty Sandstone, 35 feet; Light-brown Shale, 3 feet. *L. F. Coal*, 1½ feet. Fire-clay, 4 feet; Shale, light brown, 7 feet; blue, 2 feet; olive, 6½ feet. Shale and slaty Sandstone, 12 feet; Brown Shale, 30 feet. *Kittanning Coal*, 2½ feet; Light Shale, 7 feet; and Shale, argillaceous, micaceous, sandy, brown, and drab, slaty, 40 feet; Shale, blue, 13 feet. Ferriferous Limestone (?) 1½ feet; Shale, slaty, 6½ feet; Sandstone, 4½ feet. *Clarion Coal*, 1¼ feet; Shale, olive and brown, 7 feet; Sandstone, 19 feet. *Brookville Coal*, 2 inches; Brown Shale, 26½ feet; Tionesta Sandstone, upper, 8½ feet exposed. The level of the Beaver River is here 69½ feet above that of the Ohio at Bridgewater.

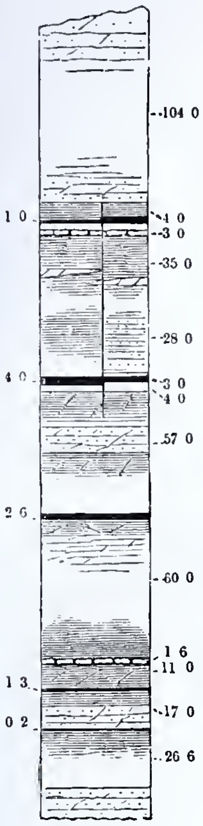


Fig. 430.—Beaver River.

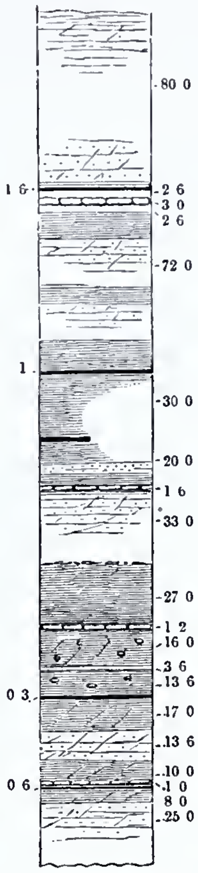


Fig. 431.—Old Brighton.

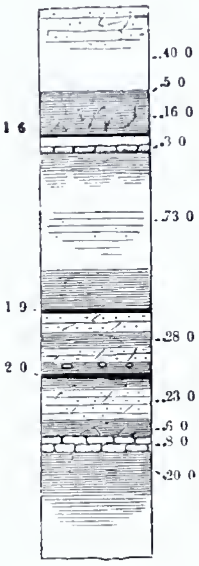


Fig. 432.—Below New Brighton.

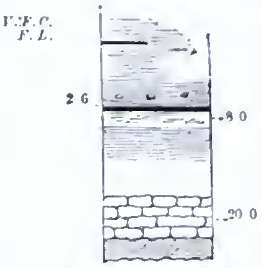


Fig. 433.—On Ohio River.

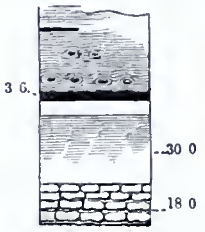


Fig. 434.—Ohio River, Six-Mile Run.

Upon a fork of Trough Run the following series of rocks was observed, and used to complete the upper part of vertical column, Fig. 430 :—

To top of hill, 25 feet. Slaty Sandstone, &c., 104 feet. *U. F. Coal*, 3 feet; Brown Shale, 84 feet. *L. F. Coal*, 4½ feet—a semi-cannel coal, not soiling the fingers in handling it. This variation from 1½ to 4½ feet takes place within the space of a quarter of a mile.

The absence of the great Ferriferous Limestone in this Trough Run section is remarkable.

By careful comparison of the columns containing it, it will be found to diminish constantly N.W. from the medial line of the Sixth Basin. The impure limestone, 1½ feet thick, abounds in organic remains. This is replaced in a little run at the back of Old Brighton, by a bed of black calcareous shale, studded with small fossil-shells.

In a small gully below Old Brighton Bridge, and above Patterson's Dam, the following section (see Fig. 431) was obtained :—

Sandstone, thick and thin, 80 feet; Brown Shale, 2½ feet. *U. F. Coal*, 1½ feet; Fire-clay, 2½ feet. *F. Limestone*, 3 feet; Fire-clay, 3 feet; Shale and Clay, 12 feet; Shale, fossiliferous, ferriferous; Shales alternating with thin sandstones, with many fossil plants, 60 feet. *L. F. Coal*, 9 to 12 inches; Clay and shale, 17 feet. Interval containing the *Kittanning Coal*, 12 feet; Shales, 13½ feet; Argillaceous Sandstone, 4 feet; Shale, calcareous, 3 feet; *Arenaceous Limestone*, 1 to 2 feet; Slaty Sandstone with calcareous argillaceous shales, 33 feet; Drab Fossil Slate and Brown Shale, 27 feet. *Ferriferous (?) Limestone*, 14 inches; Blue slightly bituminous Slate, with ore, 16 feet; Fire-clay 3 feet; Light-coloured Ferriferous Shale, 13½ feet; Argillaceous Sandstone, 2 feet; *Bituminous Shale*, 3 inches; dove-coloured

Shale, 17 feet; Reddish-brown Sandstone, 13½ feet; Shale, 10 feet. Limestone, 1 foot. Coal, 6 inches; Brown Shale, 8 feet; Flaggy Sandstone, 25 feet exposed to water-level, 54½ feet above Ohio water-level at the mouth of the Beaver River.

Here it will be seen that 130 feet of shales, and massive (Freeport) sandstone, have dwindled down to 28 feet of shales and thin sandstones, between the Kittanning and Lower Freeport coals, almost wholly removing the elsewhere so strongly marked partition between the Clarion and Freeport series of Coal-measures.

The following section (Fig. 432) was got from a run opposite, and a short distance below, New Brighton:—

Slaty Sandstone, to the top of the hill, 40 feet. Drab-coloured Shales, 5 feet; Bluish grey, 16 feet. *Upper Freeport Coal,* small; Fire-clay; Shale. *Ferriferous Limestone,* nodular, 3 feet; Shales, sometimes bituminous; Slates, Flags, probably 70 feet; Brown Shale, 3 feet. *Lower Freeport Coal,* 1½ to 2 feet; Flag-sandstone, 11 feet; Shales, 6 feet; Ferriferous, 11½ feet. *Kittanning Coal,* 2 feet; Shale, slaty Sandstone, 23½ feet; Shales, 6½ feet. *Ferriferous Limestone,* 8 feet; Shale, &c., 20 feet—to the river about 30 feet.

The small section taken at Fallston, directly opposite, differs materially from its proper representative portion in the section just given, as will appear from the following description:—

Lower Freeport Coal; Brown and olive Shales, 40 feet. *Kittanning Coal,* good, 3 feet; interval of 55 feet. *Ferriferous Limestone,* here only 1 foot thick, but rising in the hills, and increasing in thickness and pureness Northwards, until it enters the New Brighton Section (Fig. 432) as 8 feet thick.

The hills in the neighbourhood of Phillipsport are crowned by the representative shales of the Freeport Sandstone.

The Upper Freeport Coal rises from beneath the Ohio River, in the neighbourhood of Crow's Run, towards the N.W., at an angle of one degree. Its final outcrop ranges through the S. portion of Little Beaver Township: it ranges therefore, ever varying in thickness and quality, through Chippewa, Brighton, South Beaver, and Ohio townships.

North of the Ohio, and W. of the Beaver River, the variegated shale of the Barren Measures is not discoverable, but it occurs in New Sewickly on the E. side, and likewise S. of the Ohio, in Moore and Green townships. The N. corner of Economy Township may have the small fossiliferous limestone which overlies the shale.

The *Kittanning Coal-Bed* has been opened on the banks of the Ohio, below the mouth of the Beaver River, in several drifts a little below the village of Phillipsburg. It rests upon a bed of good fire-clay, which in turn overlies brown shale and slaty sandstone, while the upper margin of the Ferriferous Limestone is just below the water-mark. The roof of the coal is brown shale containing a *Pecten,* and above this other ferriferous shales, and then sandstones. Above the coal is brown shale containing a few scattered nodules of blue argillaceous iron-ore. The layer of thin shale next the coal, and which forms its roof, is slightly bituminous, and occasionally contains a small Pecten. Above the shale is a thick mass of alternating shales and slaty sandstone.

Farther down the same side of the river, the fire-clay is wrought, and the bricks sent to Pittsburg; and also on the opposite side of the river, 3 miles below Beaver, where it is 8 feet thick. The clay is good, and the bricks have hitherto found a good market. The coal resting upon it is 2½ feet thick, and probably 30 feet above the Ferriferous Limestone.

At Six-mile Run (see Fig. 434), at a small village called Industry, the Kittanning Bed yields 3½ feet of excellent coal. Beneath it is a bed of slaty sandstone, the lower part of which is in some places massive, exhibiting, locally, highly-inclined planes of deposition. Above the coal-seam is a similar brown shale with that at Phillipsburg, containing the same kind of argillaceous bluish iron-ore. This latter continues up the hill as far as the strata are exposed, probably 45 feet. From this bed, which is generally miscalled "The Fallston Vein," the inhabitants of the surrounding country and the various manufactories draw their chief supply. Indeed, it is the only bed, from the mouth of the Beaver River to the Ohio State line, that can be depended upon, and the fuel obtained from it is certainly of a very superior quality.

The *Ferriferous Limestone* at the Two-mile Run is from 18 to 20 feet thick, of excellent quality, bluish-grey in colour, fossiliferous, and 40 or 45 feet above the water-level. It rises Westward, showing itself again at the mouth of Rock Run with a soft, clean-grained, yellow, massive sandstone covering it; and again at the Run, 3½ miles from Beaver. At Six-mile Run its upper edge is at low-water level.

All the strata, from the Ferriferous Limestone upwards, may be found upon the tributary waters of the Little Beaver Creek.

We will now resume the description of the Fifth and Fourth Basins, and carry forward that of the country lying N. of the Conemaugh or Kiskiminetas River, along Red Bank, Mahoning, Crooked, and Black-Lick creeks.

CHAPTER XIX.

COUNTRY WATERED BY THE RED-BANK CREEK, JEFFERSON COUNTY—FIFTH BASIN.

Brookville is situated in the Fifth Basin, 5 miles by the turnpike from its Eastern, and 10 miles from its Western bounding axis.

The Vespertine rocks appear in the valley of the Sandy Lick Creek at Brookville. The Seral conglomerate covers with its fragments the low grounds along all the watercourses, and overspreads much of the country to the N., from which a violent denudation has swept the upper rocks, except in isolated patches forming hills, containing at their summits (especially those towards the Clarion River) the Ferriferous Limestone.

The tracing of the conglomerate is rendered more difficult from its great thickness, amounting nearly to 100 feet, and from the proximate position and similar appearance of the Tionesta conglomeritic sandstone, 50 or 60 feet thick, which overspreads it. Towards the Clarion, the lower mass becomes a true conglomerate, containing pure white pebbles regularly circumbedded, and never larger than a common chestnut. The millstones cut from this rock are never sought for lower down the Clarion than the Armstrong Mills, 3 miles above the Jefferson County line. Below this the rock loses its conglomeritic character. Much building-stone has been cut at the mouth of Clear Run, 5 miles higher up, and also as high up as 15 miles above the mills: this seems the N.E. limit of the pebbly portion of the formation. At Ridgeway it is a mere sandstone. It is seen as a conglomerate in all the ravines of Sandy Lick and Red Bank creeks as far down as Troy, where it sinks beneath the water-level.

The Tionesta Sandstone covers much ground on the road from Armstrong's Mills to Brookville, presenting no cliff exposures, but filling the valleys of the little streams, and covering the flats with fragments: the whole country rolls so gently, that its geological level scarcely varies by one coal-bed.

Beneath the Tionesta Sandstone lies the Tionesta Coal, seen around Troy and elsewhere, and opened half a mile W. of Brookville, a little N. of the turnpike, in the bed of a small run; it occurs in the following strata:—

Hill of soft shales and light sandstone, 50 feet; A wash of slate and shales, 10 feet; Black Slate, 2 feet. Coal, cannel, 2 inches; good coal, 13 inches; slaty, 1 inch; good coal, 3 inches; supported by massive white sandstone.

The pressure of the shales above this exposure incline the observer to consider it a thinner section of the Brookville Coal.

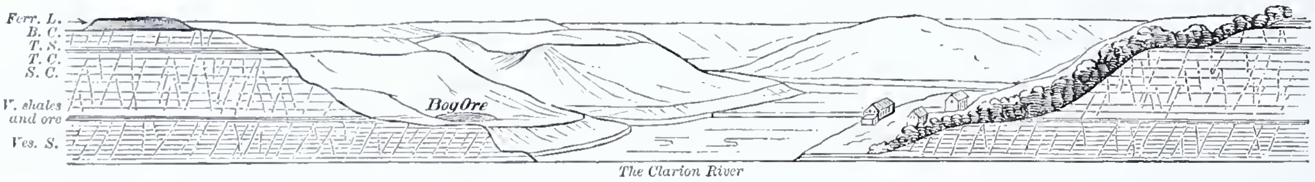
The Brookville Coal-bed is seen upon the hills back of the town, and on the turnpike towards Clarion. It outcrops towards the fifth axis about 5 miles W. of Brookville, and measures 3 or 3½ feet in thickness; also around the sides of a high hill, 6 miles from Brookville on the Warren Road, 60 or 80 feet below the summit, upon which lie the fragments of the Ferriferous Limestone-bed and its valuable ore. At the foot of the hill, below the coal, the outcrop of another bed (the Tionesta Coal) is seen in the opening, appearing thus:—

Cannel Coal, 1 foot; Clay, 1 foot; Good Coal, 1 foot. The interval of from 40 to 60 feet is evidently occupied by (the Tionesta) flaggy sandstone.

The Ferriferous Limestone is seen 2 miles S. of Armstrong's Mills, and the Brookville Coal below it; but between the two there is a bed of superior iron-ore several inches thick, and above the iron ore (which is not the Ferriferous Limestone ore) is a band of black slate, 2 feet thick, with a few inches of coal, and floored by micaceous sandstone, 5 feet thick, crossed in all directions with the black impressions of the stems of fossil plants. This may be the representative of the Clarion Coal-bed, as in the Strattonville Section (see Fig. 413, p. 569).

In the isolated district of Coal-measures enclosed between the Sandy Lick and Mill creeks N.E. of Brookville, at its N. end, a ridge contains the Ferriferous Limestone.

Fig. 435.—Armstrong's Mill, Clarion River.



On the Curwensville Turnpike the Ferriferous Limestone is not observed, but occurs not far N. of it on the road to Toby Creek. A coal-bed of no considerable thickness (the Brookville Coal) has been opened below it.

The hill, ascending from the Brookville bridge eastward, is composed, at its base, of Vespertine sandstones: these form cliffs along the water's edge at Port Barnet, below the sawmill, where is a quarry of grey flagstone. The rocks of this formation may be thus characterised: They are usually greenish, yellowish, or olive-coloured sandstone layers, from 1 to 5 inches in thickness, finely-grained, argillaceous, containing peroxide of iron in hollow concretions. Shales and shaly sandstone in layers alternate with the flags, and constitute a larger proportion of the whole. They separate the formation also into belts, and greatly predominate at its upper limit, where they contain the shelly argillaceous iron-ore. From 30 to 40 feet of these upper shales and flags are seen in the valley of the Sandy Lick.

Down the Sandy Lick Creek, 2½ miles E. of Troy, the Ferriferous Limestone appears, thin and blue, with a sandstone roof. Twenty feet below it is the Clarion Coal-bed, 1½ feet thick. It occurs again in the road immediately below the Little Run, ascending the hill to Troy. Here it is 4 feet thick. The Clarion Coal, opened below it in several places, is 2 feet thick. The Kittanning Coal was not discovered above the limestone.

One mile below Troy the following section (see Fig. 436) was obtained:—

Sandstone, *Freeport*, 50 feet, to the top of the hill. Shale and Sandstone, 75 feet. *Kittanning Coal*, 2 feet; Brown Shale, with compact oolite iron-ore, 30 feet. *Ferriferous Limestone*, 4 feet; Shale and Slate (ore in lower part), 30 feet. *Clarion Coal*, 14 inches. Shale, 55 feet. *Brookville Coal*, 3½ feet; Shale and Slate to bed of the creek, 45 feet. The Freeport Sandstone covers the country upon the road to Kittanning.

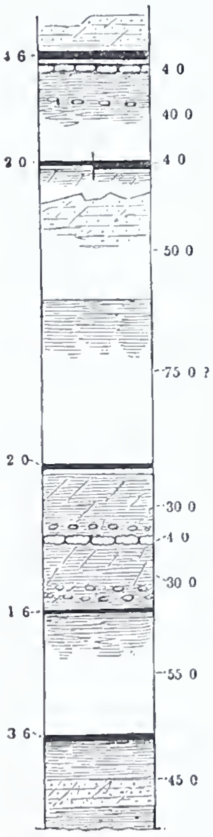


Fig. 436.—One mile below Troy.

The *Lower Freeport Coal-Bed* is first met with capping the highest hills on the Red Bank Creek, 6 miles below Troy. It is opened at the Old Tavern, 4 or 5 miles farther towards Kittanning, as in the following section—(see Fig. 438):—

Shale; *Upper Freeport Coal; Freeport Limestone;* Sandstone, 50 feet. *Lower Freeport Coal*, 4½ feet. Freeport Sandstone (a few pebbles), 50 to 60 feet; Shales, &c., 75 feet. *Kittanning Coal*, 2½ feet; Sandstone, flaggy, 45 to 50 feet; Dark Shales, 10 feet. *Ferriferous Limestone*, 6 feet; Shale, olive and yellow, 20 feet. *Clarion Coal*, in the bed of the creek.

These strata rise towards the fifth axis as we descend the Red Bank Creek. The Ferriferous Limestone is repeatedly exposed along the creek, and at a considerable height above the mouth of Leatherwood Creek.

The Lower Freeport Coal is opened on the hills half a mile S. of the tavern, about 175 feet above the creek; it is of a good quality, and 3 or 4 feet thick. Its roof is formed by 10 feet of brown shale: no limestone is visible.

The Lower Freeport Coal is well seen on a little run which enters the Red Bank 3½ miles below Smith's Tavern, and 2 miles S.E. of New Bethlehem. It is here, at Brown's, 10½ feet thick, the uppermost 8½ feet of the bed consisting of excellent cannel-coal, compact, and breaking out in pieces of considerable size, with a conchoidal fracture. Two feet of ordinary bituminous coal underlie the cannel coal, without graduation or interpolation, and this again rests upon black slate. Above the coal are 20 feet of soft brown shales, upon which are sandstones supposed to be members of the Mahoning Sandstone, above the Upper Freeport Coal. A similar coal-bank, supposed to be upon the same Lower Freeport Coal-bed, exists on Pine Creek (marked Beaver Creek on the State Map), 5 miles S.E. of this locality.

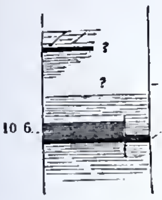


Fig. 437.—Brown's Cannel Coal.

A terrace, replete with springs, was supposed to mark the presence and position of the Upper Freeport Coal-bed, about 30 feet above the outcrop of the cannel coal.

Three miles E. of the Old Tavern we have alluded to on Red Bank Creek, there may be seen a bed of coal (Upper Freeport Coal), probably 4 feet thick, under which appears the Freeport Limestone. Gradually rising to a higher level, towards the N.E., the Upper Freeport Coal-bed appears to make its final outcrop in the centre of the basin, on the steep hills which bound the main stream of the Little Sandy Lick. At this line, the area occupied by this seam, and the Freeport Limestone under it, cannot be more than 2½ or 3 miles wide; but as the basin deepens S., this area gradually widens, and the outcrops separate, until the W. one arches over the fourth axis, 2 or 3 miles beyond where the latter has crossed the Mahoning Creek. The W. outcrop traverses the high hills which overlook the Red Bank Creek on its S. side, and then at the Olean Road takes a more South-easterly direction towards the Mahoning Creek.

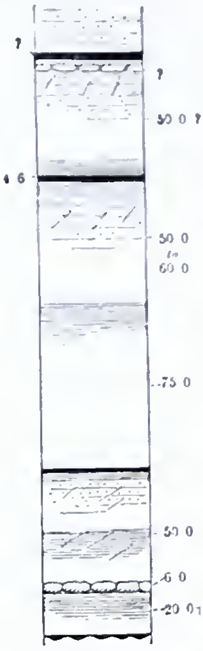


Fig. 438.—Red Bank, 6 miles below Troy.

At New Bethlehem, exposures of the rocks of the Clarion series are quite numerous. The *Clarion Coal-bed,* 5 feet thick, is opened 15 feet above water-level; roof, soft black shale, 8 feet exposed (see Fig. 439.) The Ferriferous Limestone, 4 feet exposed, hard, dark-blue, fossiliferous, is opened 25 or 30 feet above it; and still higher up, the Kittanning Coal-bed, 3 feet thick, good, with brown-shale covering. The Ferriferous Limestone is again seen at various places, 50 feet below the tops of the hills.

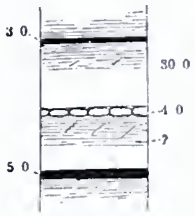


Fig. 439.—New Bethlehem.

The Ferriferous Limestone appears at Reynolds' and Schunk's Furnace, bearing its proper iron-ore. The limestone is grey, and about 6 feet thick. The ore overlies it, varying in thickness from a few inches to 3 feet. Below the limestone lies another bed of equally good ore, more regular, and averaging 9 inches in thickness. The ore is richest at the outcrop, where the carbonate of iron has been converted into the peroxide. No chert is seen.

Above the ore rest olive shales, perhaps 40 feet in thickness (Fig. 440), and over them the Kittanning Coal-bed, 30 inches thick, of poor quality, containing nodules of sulphuret of iron, and roofed by bituminous and brown shales. The hill is capped by the massive Freeport Sandstone.

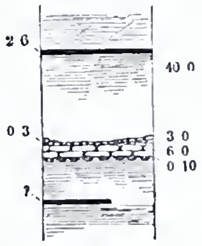


Fig. 440.—Reynolds' and Schunk's Furnace.

Descending the Red Bank, the Seral conglomerate and Tionesta Sandstone appear, but no coal is apparent between them; exposures are rare.

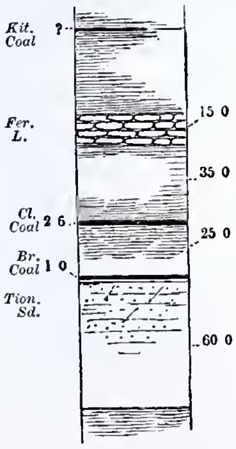


Fig. 441.—Mouth of Mahoning.

The Freeport Sandstone is the surface rock along a strip of country where the fifth axis runs S.W., after crossing the Red Bank Creek, 2 or 3 miles below the Furnace. This strip of country is in consequence sandy and barren. The following section (see Fig. 441) was made at the mouth of the Mahoning Creek:—

Ferriferous Limestone, 15 feet; Shale (ore), 35 feet. *Clarion Coal,* 2½ feet; Shale, &c., 20 feet. *Brookville Coal,* 1 foot. Tionesta Sandstone, massive, 60 feet; Shale, silicious, 25 feet; Olive bituminous Shale, 15 feet. *Tionesta Coal,* 1½ feet. Seral Conglomerate, massive, also shaly, 100 feet; Shale, sandy, partly carbonaceous, with seams of calcareous sandstone, from ¼ inch to 1 inch thick, 20 feet. Bituminous Shale, 3 inches; *Sharon Coal,* 2½ inches; Shale, sandy above, bituminous below, 3½ feet; *Coal,* 6 inches;

thin bituminous Slate, with some silicious layers, 11 feet ; *Coal*, 1½ inches ; Blue sandy Clay, 2 feet ; Slaty Sandstone, 25 to 30 feet, to the level of the Mahoning Creek.* These soon disappear beneath the water, with a dip of 5° S., 12° E.

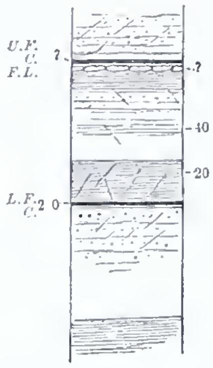


Fig. 442.—Two miles above mouth of Mahoning Creek.

None of the hills around are high enough to have the Lower Freeport Coal-bed, but both the Freeport Limestone and Upper Freeport Coal-bed are seen on Scrubgrass Creek, which enters the Mahoning 2 miles above its mouth (see Fig. 442). The coal is often so thinned away as to disappear, and let the Mahoning Sandstone rest upon Freeport Limestone. This is the case at the exposure on the North Branch of Pine Creek, where the Mahoning Sandstone is exposed, 60 feet thick, capping the hill. Here the lower shales of the interval between the two Freeport coal-beds are mostly dark brown and black, and contain layers of argillaceous iron-ore. There seems just here to be a local dip towards the W.

CHAPTER XX.

COUNTRY ON THE MAHONING AND COWANSHANNOCK WATERS, THIRD AND FOURTH BASINS, INDIANA AND ARMSTRONG COUNTIES.

As we follow the medial line of the Third Basin S. from Luthersburg, the Clarion strata sink with it, and outcrop on its margins ; they are exposed in the neighbourhood of Punxutawney, and on many of the tributaries of the Mahoning Creek. But in this region, as upon the Red Bank, the Lower Freeport Coal group, next above, is the principal one, for the Upper Freeport Coal is frequently absent, and the Elk Lick Coal seems to have dwindled again to insignificance.

At Punxutawney, the Mahoning Creek flows between slopes from 100 to 150 feet in height, abrupt on the S. bank, and gentle on the N., because the dip is S.E. The general upland level rises W. in obedience to the third axis.

At Punxutawney, the *Lower Freeport Coal-bed* underlies the village at a depth of from 20 to 40 feet. It makes its appearance upon the axis, which runs within a mile to the N.W. of the village. There the following section (see Fig. 443) was obtained :—

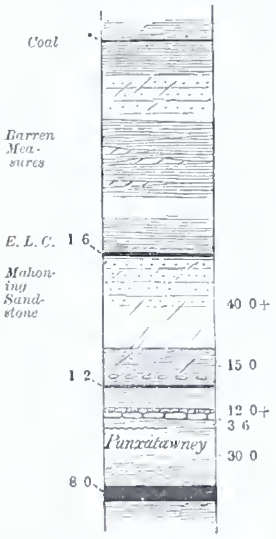


Fig. 443.—One mile W. and two miles S.W. of Punxutawney.

Sandstone ; variegated Shales and Sandstones. *Elk-Lick Coal*, 1½ feet ; Mahoning Sandstone, from 40 to 50 feet ; Shale, 15 feet. *Upper Freeport Coal*, with a band of fossiliferous calcareous Shale above it, 15 inches ; Dark Shales, 15 feet. *Freeport Limestone*, 3½ feet ; Shales, 30 feet.

The Lower Freeport Coal is 8 feet thick as it appears in the Little Run, 2 miles S.W. of Punxutawney ; the coal is solid and good, and dips with the run towards the S.E. At the surface the outcrop of this large bed was only 2 feet thick in one place, and 4 feet in another. At the head of the run it has also been opened.

The Freeport Limestone, half a fine-grained blue carbonate of lime, and half a carbonate of iron of similar aspect, makes its appearance upon the bluff, near the sawmill, running along about 15 feet above the water of the creek, and again in the mill-race above the village. It may be compared with the bed at Reynolds', on Sandy Lick Creek, and is doubtless the same. A band of black fossiliferous calcareous shale, found above it, is at least persistent enough to be found again down the Mahoning Creek, at Smicksburg.

---

* The lower portions of the section were taken from the exposures on the N. side of the stream ; the upper portions, from behind Templeton's Tavern.

The limestone rises as we descend the creek, and at Kinsel's is from 40 to 60 feet above the water-level. Above it, scattered thickly over the fields in patches, are to be seen many pieces of a honeycomb pure ore, of excellent quality and in great abundance; but the band does not appear in place. We may venture the assertion, that it is part of the semi-ferruginous Freeport limestone-bed itself, the highly ferriferous fragments of which have assumed this aspect in weathering. The fragments are spread over a long slope, at the head of which (perhaps 40 feet above the limestone) is a bench doubtless containing the Elk Lick or possibly the Upper Freeport Coal-bed. Beneath this supposed coal-bed is seen the outcrop of a conglomeritic sandstone (Mahoning?) Erratic blocks, broken from this formation, lie strewn upon all the bottoms of the Mahoning Creek in this neighbourhood; some of them are of great size, and quite angular. There lies a sandstone stratum upon the 6 feet of shale covering the Lower Freeport Coal (6 feet thick), 5 miles below Punxutawney, but of a wholly different character, being flaggy and homogeneous.

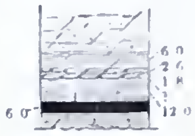


FIG. 444.—Mean's, Mahoning.

Here the Freeport Limestone is in two layers, the uppermost 20 inches thick, of good blue carbonate; then 2½ inches of bright-yellow clay; and underneath it, 12 inches of limestone is exposed, which may be thicker. Lying scattered about the quarry, as useless, are slabs of grey carbonate of iron, 1½ inches in thickness, and also of a shaly, silicious, hard, and heavy ferruginous semi-limestone stratum, recognisable also in the Smicksburg Section.

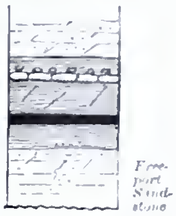


FIG. 445.— Freeport Limestone, 5 miles below Punxutawney.

At Templeton's, where the Lower Freeport Coal is only opened as a 3½-feet bed, with shale roof and slate floor, at the level of the creek, the Freeport Limestone, 10 or 12 feet above it, is a band 2½ feet thick, floored by shelly sandstone, looking like a decomposed ferruginous rock. At another opening it appears in three layers, thus:—

Pure black Limestone, 4 inches; Black Slate, 3 inches; Yellow Limestone, 4 inches; Clay, 3 inches; Limestone, 2 feet; Slate.—(See Fig. 446.)

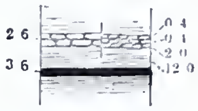


FIG. 446.—Frampton's.

At Kinter's Mill, where the third axis crosses the Mahoning Valley, the Freeport Limestone just reaches water-level, so rapidly has the axis declined from the neighbourhood of Punxutawney. Above it is a small bed, the Upper Freeport Coal; and high up towards the Barren Measures, which occupy all the high lands, are calcareous shales, with a 6-inch bed of coal upon them. These Barren Measures occupy the whole basin to the E. and S. of Punxutawney, yielding no workable coal, and no large bed of limestone, but displaying the conglomeritic Mahoning Sandstone everywhere as their base rock.

Near the head-waters of the Little Mahoning Creek, a limestone-bed is seen 20 feet below a coal-bed, both unidentified; at a level 60 feet lower, springs issue along a terrace, where they have deposited an extensive ore-bog at the village of Robertsville.

The limestone appears again at a place 2½ miles S.E. of Simpson's Mill, 4 miles W. of Robertsville. The strata dip W. after passing the mill; and at a place 2½ miles W. of it, a coal-bed, 2 feet 10 inches thick, is seen 4 feet above the water in the creek. A short distance below this, two other coal-exposures appear, one at a height of 50, the other of 30 or 35 feet above the water. The position of the uppermost (evidently the Upper Freeport Coal) seems to be signified by the presence of the limestone, at a level a little lower than its own, a short distance down the creek.

Two miles E. of Dill's Mill, 5 miles below Simpson's Mill, and at the crossing of the Indian Road, bluish-black, fossiliferous calcareous slates (the black limestone-strata of the Barren Measures) are seen on the N. side of the road, at a spring which issues 65 or 70 feet above the level of the creek. Descending the creek three-fourths of a mile, a limestone in two layers, separated by 1 foot of crumbly shale, is seen lying in the bed of the stream; and this continues to be visible at water-level to within 400 or 500 yards above Dill's Mill. Eighteen feet above the limestone there is a coal-bed (Upper Freeport Coal) 5 inches thick; the interval greenish and brownish shales, with some sandstone. Coal-roof, blue shale, 12 feet.—(See Fig. 447).

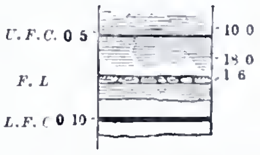


FIG. 447.—Dill's and Ewing's Mill, Mahoning Creek.

At Ewing's Mill, still farther down the creek, in a little run, is seen a bed of very pure carbonate of iron 18 inches thick, in layers of 4 and 5 inches thick, with concretions of silica, while masses and veins of apparently pure carbonate of lime subdivide the ore. These limestone portions of the bed have a semi-crystalline structure, breaking into columns and cubes. Above it lie 10 feet of shale, and a thin coal (Upper Freeport ?). The massive debris of a conglomeritic sandstone (the Mahoning ?) fill the run and cover the slopes; while the great shale-formation of the Barren Measures is seen to form the high ground, traversing "the Hog-Back," and descending again to Kinter's Mill.

The Lower Freeport Coal-bed, 10 inches thick, appears in the race-way of Ewing's Mill, certainly not more than 20 feet below the limestone, which is 17 feet above the water-level below the mill; it is there capped by 5 inches of iron ore. On a little stream near by, the limestone again appears, and 16 or 17 feet above it is said to be an Upper Freeport Coal-bed, 10 inches thick. Fragments of a limestone stratum of the Barren Measures lie strewn upon the road near the mill, at an elevation of 80 or 90 feet above the water. These fragments are flat, 6 or 8 inches thick, and full of small clusters of crystallised carbonate of lime, and the same minute shells that are found in the Freeport Limestone.

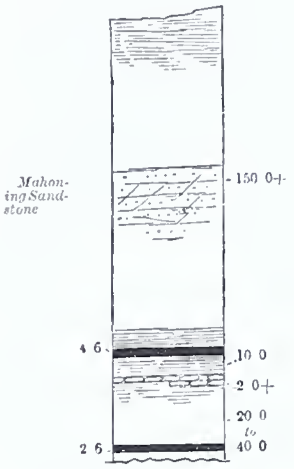


FIG. 448.—Smicksburg.

At Kinter's Mill the E. dip has raised the Freeport Limestone to a height of 40 or 50 feet above the stream. One hundred feet above the limestone, 2 miles S.W., appear the black fossiliferous limestone strata, over which is a coal-seam 4 inches thick.

Three-fourths of a mile above Smicksburg, the Freeport Limestone is about 18 feet above the creek, and apparently non-fossiliferous. At Smicksburg the Lower Freeport Coal, 2½ feet thick, lies in the bed of the creek at the Turnpike-crossing, and is cut by the village wells. It underlies the limestone from 20 to 40 feet. The limestone, with its fossils, stands at an elevation of 43 feet upon the N. hill-slopes.

About 10 feet above the limestone several old gangways have been driven in upon the Upper Freeport Coal, 4½ feet thick (see Fig. 448); above which are the fragments of the Mahoning Sandstone, quite conglomeritic. The land, back from the creek, is very high, but composed of Barren Measures.

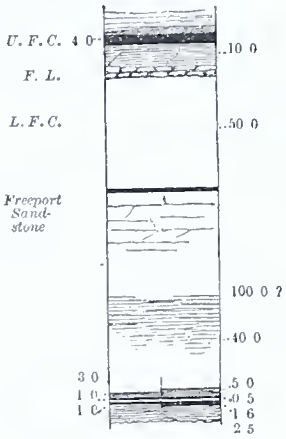


FIG. 449.

The Freeport (?) limestone appears 80 feet above the water, near the forks of the Great and Little Mahoning.

At the crossing of the Middletown Road, over the great Mahoning Creek, the strata begin to dip more steeply, and soon the Ferriferous Limestone and its overlying Kittanning Coal rise from the water.

The Upper Freeport Coal is seen N.E. of the salt-works, a little East of the road, 150 or 200 feet above the creek, the Freeport Limestone occurring at a little lower level opposite.

The fourth axis crosses somewhat below Glade Run, but so rapidly does it decline, like all the others, to the S.W., that on the Cowanshannock it does not lift the Ferriferous Limestone to water-level, although here that bed is at a considerable height in the hill-sides.

On Pine (marked Beaver) Run, above Smith's Sawmill, was obtained this section (see Fig. 450):—

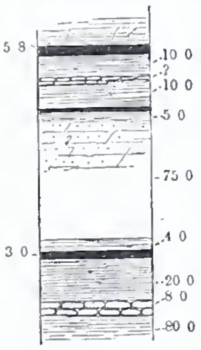


FIG. 450.—Smith's Sawmill.

Sandstone, 10 feet. *Upper Freeport Coal*, 5 feet 8 inches; Olive Shale, 10 feet. *Freeport Limestone;* Blue Shale, 10 feet. *Lower Freeport Coal;* Shale, 5 feet; Sandstone (Freeport), 75 feet; Black Slate, 4 feet. *Kittanning Coal*, 3 feet; Olive Shale, 20 feet. *Ferriferous Limestone*, 8 feet; 80 feet above the creek by estimation.

The Upper Freeport Coal-bed throws its W. outcrop across the Mahoning Creek, 5 or 6 miles above its confluence with the Alleghany.

The fourth axis is crossed by the outcrop of the Upper Freeport Coal-bed, 2 miles S.W. of the Mahoning. It crosses the Cowanshannock, 8 miles from Kittanning, and brings up in the bed of the stream both the Kittanning Coal-bed and the Ferriferous Limestone, while the Lower Freeport Coal-bed, 1½ feet thick, lies near the top of the hills.

Two miles W. of Rural Village, on a farm known as Smith's Tract, the Upper Freeport Coal-bed is 150 or more feet above the creek, it is 4 feet thick, of good quality, but with a little sulphur. Ten feet below it is the Ferriferous Limestone, 6 feet thick. Fifty feet below the limestone is seen the Lower Freeport Coal, said to be 1½ feet thick. Upwards of 100 feet lower down, near the creek-level, is the Kittanning Coal-bed, thickness unknown. This locality is on the E. side of the fourth axis, and distant from it 2 or 2½ miles; dip S.E.

At Patterson's Mill the Kittanning Bed, covered by 40 feet of shales, reads thus :—

> Bituminous Shale, 3 feet; *Coal* and Slate interleaved, vegetable impressions numerous, 12 inches; *Coal*, 12 inches (7 feet above level of water); Floor, black Slate.

Lower down it reads thus :—

> Black Slate, 5 feet; *Coal*, 5 inches; Bituminous, pyritous slate, 18 inches; *Coal*, 15 inches; Slaty Coal, 14 inches.

CHAPTER XXI.

THIRD BASIN, IN INDIANA COUNTY.

THE country to be described in this chapter is traversed by the waters of Black Lick Creek and Crooked Creek, and is wild and unsettled toward the N.E. It is overspread almost everywhere by the rocks of the Barren Measures, the Fossiliferous Limestone of which makes its appearance about half a mile N.E. of Indiana Town, on the road to M^cKee's Mill. It is thinner than usual, and covered by red and variegated shales: it yields no good lime.

One of the coal-beds of the Freeport series, called Stuchel's Coal, has been opened upon M^cKee's Run, 4 miles from the town, half a mile above the grist-mill, and 10 feet above the level of the creek. It is thus :—

> *Coal*, 22 inches; Greyish-black crumbly Shale, 8 to 10 inches; *Coal*, 4¼ feet; Clay and Shale. The roof is grey micaceous sandstone; dip N. 30° W.; it contains much sulphate of iron.

A bed, corresponding in position and character to Stuchel's, is opened on Hiram Thomas's land, 3 miles E. of Kellysburg, and measures between 5 and 6 feet in thickness. This same bed probably makes it appearance on Rayne's Run, a tributary of Crooked Creek; on the opposite bank its fragments of blue Freeport Limestone, at a higher elevation than that of the coal, dip rather steeply towards the W.

A bed similarly divided by a band of slate is found near the water-level on Crooked Creek, N.E. of Chambersburg. At this point a band of limestone lies 10 feet beneath the coal, but the beds have not been fully developed. In the vicinity of Marion, on the head-waters of Pine Run, a bed 5 feet thick is opened at several points. S. of this, on Buck Run, a branch of Two-Lick Creek, Messrs Chapman and O'Neal have opened a bed for their own use. The dip is W. into the Third Basin. In Green Township a bed 4 feet thick is opened by Mr Black on Dixon's Run, 1¼ miles S.E. of which a bed of the same thickness, known as Shedrich's, is underlaid by limestone. The latter is no doubt the Freeport Limestone overlaid by the Upper Freeport Coal. Descending Two-Lick Creek to a point 2½ miles above Young's Mills, we see a coal-bed 3 feet 8 inches thick, 23 feet above the creek. Below, and opposite, but at least 130 feet above the creek, is Allen's Coal-bed, about 3 feet thick.

Another bed, the roof of which is slate, with iron ore, is also about 3 feet thick; it is only 50 feet above the creek, at the sawmill. Upon the high land W. of these is seen a fossiliferous limestone stratum, 3 feet thick, over which from 10 to 15 feet is a black bituminous slate, with impressions of a Modiola; while to the N.E., at a level perhaps a little lower than the limestone, is seen a small coal-bed (see Fig. 451). The Modiola Limestone is seen 3 feet thick farther down, and half a mile to the right of the creek; and above it 12 or 15 feet there is a coal-bed said to be 2½ feet thick. The Freeport Limestone appears 10 or 15 feet above Two-Lick

Creek, at a point one mile above Young's Mills; at an equal distance above it is the Upper Freeport Coal-bed, but thin. A coal-seam, perhaps the Lower Freeport Coal, shows itself, 3½ feet thick (and said to have yet a lower member underneath, a stratum of slate), just above Young's Mills, 10 or 12 feet above the water: it enters the water 1½ miles below; and half a mile still lower down, a limestone is said to occur over it.

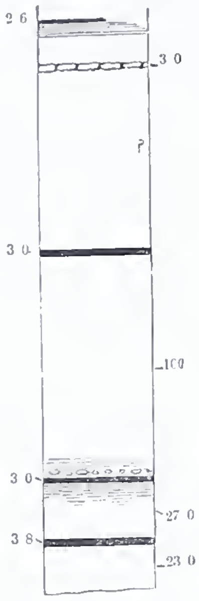


Fig. 451.—Two-Lick Creek.

Two miles below the forks of Two-Lick and Yellow creeks, in the bed of a little run to the left of the road, is a blue non-fossiliferous limestone; blue and black slates lie above it, and a thin 9-inch coal-bed. Sixty feet above these Barren Measure strata, a large Coal-bed is said to have been opened. Within a mile of Black Lick Creek, and to the N.E. of Two-Lick Creek, a 7-feet coal-bed, parted by bands of slate, has been opened. This is probably the Pittsburg Coal-bed. This Pittsburg Coal is seen on the W. side of the Two-Lick; half a mile N. of the Black-Lick Creek it is 7 feet thick. From 60 to 65 feet below the coal a highly fossiliferous limestone is seen outcropping E., the fossils being identical with those of the Freeport Limestone.

The green fossiliferous limestone strata are seen a little above the Forks, 35 or 40 feet above the level of the stream, reading thus:—

Argillaceous Limestone, studded with bivalves imperfectly preserved, 6 inches. Compact Limestone, with fewer fossils, 4 inches. Green, red, &c., Shales, in coloured bands, 10 to 12 inches thick. Green fossiliferous Limestone, 10 inches. Greenish Sandstone, 5 inches. Red Shale, 2 feet; Dark-blue Slate.

These strata are again seen 20 feet above the water in the following section, made in a little hollow 2½ miles from Campbell's Mill:—

Unknown to the top of the hill, 40 feet. Sandstone, 40 feet; Unknown, 20 feet; Sandstone, 17 feet. Red argillaceous Stratum; Sandstone, 4 feet; Slate and Shale, 10 to 15 feet; Unknown, 25 to 30 feet. Red argillaceous Shale, containing small bivalves, red argillaceous stratum, bluish in spots, 8 feet. Light green fossiliferous Limestone, 10 inches; 20 feet to the Creek-bed not exposed.

Nearly opposite this section some nodular hematitic ore, in very red shale, may be observed. The Pittsburg Coal-bed occurs at an elevation of 150 (?) feet. Half a mile E. of Gibson's Run, fragments of the non-fossiliferous limestone 3 feet thick outcrop, 60 feet beneath the Pittsburg Coal, and are visible at an elevation of 105 feet above the creek. Heavy slaty sandstone lies above; 50 feet below it are the variegated shales.

The Pittsburg Coal is seen on the W. side of the Indiana Road, and also a mile from Campbell's Mill, but no farther N. Near the mouth of the Black-Lick Creek the following section was obtained:—

Olive Slate, 20 feet. Blue Slate. Unknown, 15 feet. Calcareous Clay, 2½ feet. Red and Green Shales, 6 feet. Green Shale, 10 feet. Unknown, 25 feet. Green fosssiliferous Sandstone, 10 inches. Unknown, 10 feet. Red Shale, 3 feet; to the level of the creek, 54 feet. A slide has covered the hill-side only 20 feet above the water with fragments of the green fossiliferous limestone stratum.

Just at the forks of Two-Lick and Black-Lick creeks a coal is cut by the railroad; it is about 4 feet thick, and is underlaid by a thin band of limestone. The railroad also cuts a small seam 1 foot or 1½ feet thick S. of Smith's Station. On the hills in the neighbourhood the Pittsburg Bed is wrought.

Descending Crooked Creek, on the main Indiana Road, 1½ miles below the crossing, is McCallam's Coal-bank, on the Upper Freeport Coal-bed, 22 inches thick. Below it is the limestone in the bed of the creek; this is again seen 2½ miles down the stream, below which it is abundant at water-level. Four hundred yards down the creek, and near the water, a coal-bed 3½ feet thick is opened.

Below this point the Barren Measures compose all the land above water-level, keeping the coal-beds under and out of sight, to be mined hereafter only by shafts. The variegated shales approach water-level. At Shelocta Settlement, 1 mile from the county-line, the contrary (Easterly) dips commence, and bring up the coal-beds. There appears first, not far below Shelocta, the thin black fossiliferous stratum before spoken of, and

12 feet above it a highly-fossiliferous dark-blue limestone (37 feet above the water), covered by bluish-black crumbling shales.

The Upper Freeport Coal-bed comes out a mile farther down; it is nearly 3 feet thick where it is opened from 12 to 15 feet above the stream — roof, brown shale, 9 feet. The same bed appears a quarter of a mile W. of S.; it is 5 feet above the creek, for there is here a S. dip, and it is 3½ feet thick; roof, slate, several feet, then the bedded sandstone, 25 feet exposed.—(See Fig. 452.)

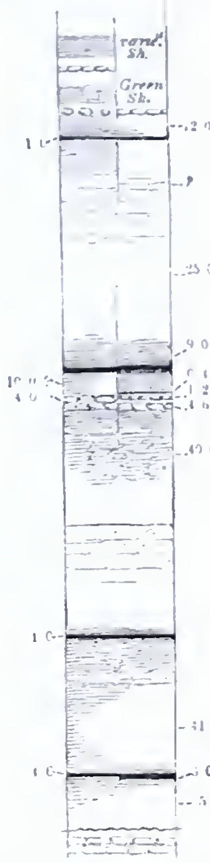


Fig. 452.—Compiled along Crooked and Plum Creek.

The Freeport Limestone is seen with its usually minute shells in the water a few hundred yards lower down, near the confluence of Plum Creek. It may be 9 feet below the Upper Freeport Coal.

On Plum Creek, half a mile above its mouth, near the turnpike, the Ferriferous Limestone is about 27 feet above the stream, thus—(See Fig. 452):—

Coal, 4 inches; Shale, 15 inches; *Limestone,* 14 inches; Shale, 2½ feet; Limestone, 4½ feet.

The run called Anderson's Run flows upon it as a floor for 2 miles, descending from the third axis from the E. Here 4 feet of it are exposed, and its few fossils are exhibited. The Upper Freeport Coal is probably from 6 to 10 feet above it, and is opened on the W. side of creek; it is 3 feet thick, and of excellent quality. Shale and thin sandstone underlie the coal. Two miles above the Forks, below Hill's Mills, is seen the outcrop of a 12-inch coal-bed, which, lying from 70 to 100 feet above the Freeport Limestone, is both the black fossiliferous, calcareous, bituminous stratum before spoken of, and the Elk-Lick Coal-bed. The Upper Freeport Coal-bed must here be under Plum Creek bottom. A limestone, full of fossils, is visible on the W. side of the Creek Road, in a little run 3½ miles above Hill's Mill. Similar strata to those below the mill are found 2 miles S.W. of Georgeville, on very high land over which the road from Plum Creek passes. The North Branch of Plum Creek flows in the Fourth Basin. The Upper Freeport Coal is seen 8 feet above it, a mile above its confluence with the other branch: it measures 3¼ feet: it is from 14 to 16 feet above the water a mile still higher up, but no limestone is visible beneath it.

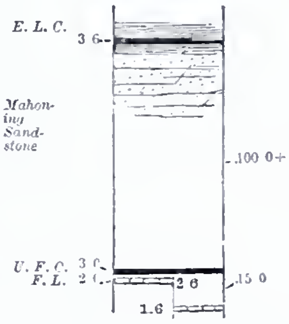


Fig. 453.—Crooked-Creek Bend.

On the W. side, a short distance farther up, the coal is 35 feet above the stream, and 3 feet thick; below it is the Freeport Limestone, 15 feet above the water: its fragments strew the shore. Two miles higher, at Martin's Mill, the coal is 10 feet above the water-level, and is 3 feet thick.

The country around the head-waters of the two branches of Plum Creek is singularly destitute of loose surface-stones, because composed wholly of the soft slates and shales of the Middle and Upper Barren series.

In Young Township, bordering the county-line on the S.W., several beds of coal have been opened, and wrought to a very moderate extent for neighbourhood use. One of these, exceeding 4 feet in thickness, is opened at Patterson's, N. of the township line. The same bed is found at West Lebanon. One and a half miles S.W. of West Lebanon, coal is opened by Mr McMeans, and near the steam sawmill, W. of Blackleg's Creek, the Pittsburg Coal is developed as a bed of more than 11 feet thickness. In the neighbourhood of Jacksonville a coal-bed, 3 feet 6 inches thick, resting within 10 feet of a bed of limestone, is opened at various points.

The systematic description of the Conemaugh country will follow in a future chapter.

CHAPTER XXII.

FOURTH AND FIFTH BASINS—KITTANNING AND FREEPORT—CROOKED CREEK AND THE KISKIMINETAS.

On Crooked Creek, 2½ miles below Plum Creek, the Upper Freeport Coal is seen 12 feet above the creek, and 22 inches thick, as exposed: it soon dips under the stream. In the bend of Crooked Creek, the red and variegated shales of the Barren Measures, with nodules of hematitic ore, occur 45 feet above the stream, and fragments of green fossiliferous limestone 30 feet above it.

The Pittsburg Coal occurs upon the upland surface, three-quarters of a mile S.E. of this point on Crooked Creek.

The black limestone strata are seen rising W. under the greenish strata a fourth of a mile below the bend, and 20 feet above the creek. Over a dark-greenish slaty stratum, 10 inches thick, lies a nodular limestone, dark blue within, and full of fine bivalve molluscs; it is 5 inches thick: this, again, is capped by green shales.

Half a mile below this the Upper Freeport Coal rises to a height of 51 feet above the water-level, and is opened 3¼ feet thick: roof, bituminous shale, 1½ feet.

The *Ferriferous Limestone.*—This rock rises from the creek at Heath's; it is full of small bivalves (*Terebratula*, &c.), is flinty, thinly stratified, dark blue, and 5 feet thick. A quarry of a silicious sandstone, greenish-grey, and splitting into slabs, has been blasted in the strata 20 feet above the limestone. The slabs are used for tombstones in Middletown. These sandstones are largely developed in the bend of the creek below the next sawmill. A coal-bed, 1½ feet thick, is here from 20 to 25 feet above the water: the limestone is nowhere visible. A section made in the lofty sides of the valley at this place reads as follows—(see *ante*, Fig. 451):—

Mahoning massive Sandstone, 50 feet; *Upper Freeport Coal*, irregular, estimated to be 200 feet above the creek, 3 feet; Unknown, 15 feet. Freeport Limestone, 18 inches; Unknown, 10 feet. Sandstone and Shale, 40 feet; Freeport Sandstone, 50 feet. *Coal*, a few inches. Shale, 16 feet; Sandstone, 4 feet; Unknown, 41 feet.

Kittanning Coal (possibly the Ferriferous Coal), 1½ feet, unknown down to the creek; but at the Salt-works, a mile below, there follows:—

Ferriferous Limestone, here 22 feet above the creek, and full of fossils, 6 feet thick. The depth of the Salt Well is said to be 500 feet. A little to the E. of this appears to run the highest or axis line of the third anticlinal flexure. The Freeport Limestone, bearing its characteristic minute fossils, has fallen so far in its level by the time it has reached Pitt's Mill, 400 yards above the next Salt-works, that it is but 24 feet above the dam: it is semi-nodular, and 2 feet thick. The Upper Freeport Coal overlies it only 2½ feet, and is itself 3 feet thick. It is a thicker bed some hundred yards S.W., and the coal outcrop is 10 feet above it. A coal-bed is seen at a level 100 feet higher in the hill-side, and is (upon the supposition of the limestone being the Freeport Limestone) assigned to the horizon of the Elk-Lick Coal. Beneath it is seen a massive sandstone. If the limestone at the creek be the Ferriferous Limestone, this bed becomes the Lower Freeport Coal, supported by the Freeport Sandstone; but the fossils of the limestone seem decisive against that supposition.

At the lower Salt-works the fuel has been obtained from a gangway driven in upon a coal-bed 3 feet thick, and 60 feet above the stream.

The fourth anticlinal crosses Crooked Creek, half-way between this spot and its mouth, a mile above the bend through which the race-way is cut, but it does not bring the Clarion series to the day. At the mouth of the creek the Freeport Limestone is within 50 feet of the Alleghany River level.

At Kittanning the Ferriferous Limestone appears upon the opposite side of the river. Above the bridge it is about 70 feet above the river, and 12 feet of it are exposed. Upon it lies a stratum 5 or 6 inches thick, decomposing into a mottled iron-ore. The Kittanning Coal is 20 feet above the limestone. At the bridge these strata are much nearer the water-level. The Lower Freeport Coal, 1 foot thick, is seen on the Butler Road, which ascends the hill from the bridge, 52 feet above the Kittanning Coal. The Freeport Sandstone here seems to be above instead of below the coal, and some doubt therefore rests upon the identity of this bed with that coal, suggesting that it may be the unnamed bed seen beneath the sandstone higher up the river. The true Lower Freeport Coal-bed seems to be represented here by the uppermost of two bituminous seams, varying from 4 feet to 6 inches in thickness higher up in the series. The strata (see Fig. 454), compiled from around Kittanning, indicate as follows, descending :—

Slaty Sandstone, 35 (?) feet ; Red and variegated Shales, 15 (?) feet ; Brown Shales and argillaceous sandstone, with nodules of iron ore and bands of arenaceous limestone, 45 feet. *Limestone*, blue, black, sandy, 12 inches. *Coal*, not always present, 6 to 9 inches. Olive Shales and slaty sandstones, 25 (?) feet ; Blue Shales, 25 (?) feet. Slaty Sandstone, 60 (?) feet. Brown and blue Shales, 60 (?) feet. Slaty Sandstone, 25 (?) feet. Brown Shales, 25 (?) feet. *Upper Freeport Coal*, 3 feet. Blue compact Shale, 10 to 15 feet. *Freeport Limestone*, 5 to 6 feet. Shale and Sandstone, 30 feet. *Lower Freeport* (?) *Coal*, 4 feet, sometimes thinned away. Brown and black shales, 25 to 30 feet. *Coal*, 6 to 15 inches. Shales, 25 feet. *Coal*, 9 to 18 inches ; Fire-clay, 6 feet. Sandstone (Freeport) and shale, 46 feet. *Kittanning Coal*, 2 to 4 feet ; Fire-clay and shales, 25 feet. *Iron-ore ; Ferriferous Limestone*, 12 to 14 feet.

Descending the hill opposite Kittanning, we have the following section :—

Friable brown Shale, 20 feet ; Coarse grey Freeport Sandstone, layers contorted and broken, 40 feet. Soft brown and black Shales, containing an unnamed coal-bed 1 foot thick, 20 feet. *Coal*, 20 inches ; Coarse blue Clay, 8 feet, passing downwards into brown shale, and then slaty sandstone, 40 feet. *Kittanning Coal*, 3 feet ; Shale, 25 feet. Ferriferous Limestone, 15 feet ; Shale, 20 feet ; river.

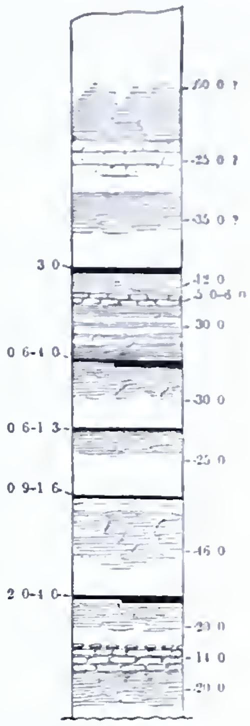


Fig. 454.—Kittanning.

In the little ravine below the town, the following imperfect section was partially levelled :—

Green Shale, 2 feet ; Light-blue Shale, 2½ feet. *Upper Freeport Coal*, 5 feet ; Unknown, 6 feet. Freeport Limestone in fragments ; Unknown (Shale, &c.), 40 feet ; Brownish-grey slaty Sandstone, 8½ feet ; Blue and grey Shale (6 to 8 feet exposed), 25½ feet ; *Coal*, 4 inches ; Shale, brown, passing into sandstone, 5 feet ; Grey Slate, 3 feet ; Unknown (shale), 29 feet ; Shale, 5 feet ; Arenaceous Shale, 3½ feet ; Sandstone, solid above, slaty below, 14 feet ; Blue Slate, 3 feet ; Bed of Sandstone, 4 to 6 inches thick, immediately upon the *Kittanning Coal*, 3 feet ; Unknown, 24 feet to the road, and 15 feet more to the river, at low water.

The town of Kittanning is built upon the Ferriferous Limestone, which is of a grey or blue colour, not containing many fossils ; it is from 14 to 16 feet thick. Its fragments cover the river-banks, until it sinks under water-level below the town. It is seen on Reynolds' farm, 1 mile N. of the town, where the Kittanning Coal also appears 20 feet above it.

Near the Court-house the Ferriferous Limestone has been quarried at the level of the town, and the buhrstone ore stripped from it over a considerable area. Along the face of the hill behind the town the Kittanning Coal-bed has been opened at various points. At Mr Nulton's opening, N. of the Court-house, it measures 4 feet in thickness, and is divided by a thin slate about a foot from the top. Followed S., it declines in thickness to 2 feet or 2 feet 6 inches. Below the rolling-mill, where it has been opened in a ravine near the railroad, it proved to be 2 feet 10 inches thick. From this point it gradually sinks beneath the river-level. Below the bed of the river the limestone was cut in a well in the ravine.

The small coal-bed next over the Kittanning Seam, and the strata immediately adjacent, are well exposed by a cutting on the Alleghany Valley Railroad, one-third of a mile below the rolling-mill. The coal presents variable dimensions, fluctuating between 9 and 18 inches, and is divided in the middle by a thin band of slate. It is immediately underlaid by a band of impure, somewhat indurated, fire-clay, varying in thickness from 2 to 10 feet. Through this are disseminated nodules of rough iron-ore. Beneath the fire-clay is an irregularly-stratified mass of highly argillaceous micaceous sandstone. The natural colour of the rock is blue, though when weathered it assumes variegated tints, chiefly light olive-green and reddish-brown. It contains vaguely-marked vegetable forms. Over the coal repose dark-blue shales, weathering rusty brown. These shales are 25 feet thick, and in some places curiously distorted. They become more compact and silicious towards the top, and a thin layer of bituminous shale and coaly matter may be seen interstratified with the mass—dip S.W. 2° to 3°.

The two small coals above mentioned are exposed in a ravine below Squire Buffington's mines, on the hill above the rolling-mill. Here they are 15 inches thick each. The Kittanning rolling-mill is supplied with coal by Squire Buffington, from a seam lying about 30 feet higher than the uppermost of the small coals. The bed, when regular, measures 4 feet in thickness, but in the mines it sometimes thins away to a mere streak. Over it 30 feet the Freeport Limestone has been proved nearly 6 feet thick; and 10 or 15 feet above this, the Upper Freeport Bed, measuring 3 feet, contains 2 feet 9 inches of available coal. The coal from all of these beds contains more or less sulphur. It is not easy to say with certainty which of the three coal-seams, between the upper limestone and the Kittanning Coal, represents the Lower Freeport Bed; nor is it here a matter of much practical importance. The strata rise North-westwards. At the Alleghany Furnace the Kittanning Coal-bed is 200 feet above water-level; whereas at the salt-works, 2 miles below it, it is but 60 feet above the stream. A slight undulation is suspected to pass from Scrubgrass Creek through the neighbourhood of the Alleghany Furnace, causing local N.W. dips; also on the North Branch of Pine Creek. The section made at this furnace, and expressed in Fig. 455, is as follows:—

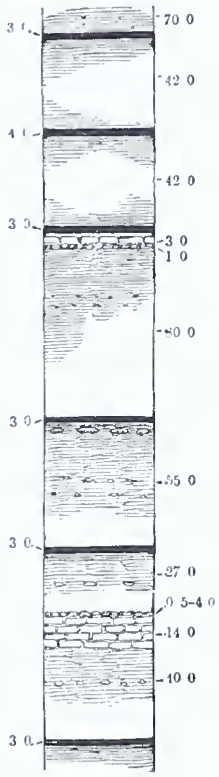


Fig. 455.—Alleghany Furnace.

Top of the hill, Shales, 70 feet. *Coal,* 3 feet. Unknown, probably Shales, 42 feet. *Elk-Lick Coal,* pure " coke-vein," 4 feet. Unknown, 42 feet. *Upper Freeport Coal,* 2½ feet. Freeport Limestone, nodular; *Iron ore,* 1 foot; Unknown strata, containing oolitic iron-ore, 80 feet. *Lower Freeport Coal,* 3 feet; Shale; Limestone in nodules; Brown and black Shale, with nodular ore, 55 feet; *Kittanning Coal,* 3 feet; Shale, with nodular ore, 27 feet; Ferriferous Limestone, overlaid by ore, from 30 to 40 inches thick, 14 feet; Brown and blue Shale, with argillaceous ore, 40 feet. *Clarion Coal,* impure, 3 feet, is 135 feet above the Alleghany River. The Tionesta or the Sharon Coal is said to have been found.

The Clarion Coal is in two bands, a fourth of a mile above the furnace. The Ferriferous Limestone is a greyish-blue rock, with a few Encrinites and other fossils. Upon it rests from 5 inches to 4 feet of iron ore, and occasionally 6 or 8 inches of chert interposed. The buhrstone or chert occurs in patches 8 or 10 yards square, and is of a yellowish-white colour and flinty substance. The lowest of the limestone layer, from 4 to 10 inches thick, is often so much of a carbonate of iron as to be useful as an iron ore. Six or more layers of nodular iron-ore run through the mass of shale below the limestone, and have been used at the furnace. The Tionesta Sandstone, and part at least of the Seral Conglomerate sandstone, are here above the water-level.

One mile N. of the furnace ranges the outcrop of the Upper Freeport Coal. This bed doubtless exists in the high land at the forks of the Franklin and Waterson's Ferry roads. Its main outcrop is seen on the Butler Turnpike, one and three-fourths of a mile from Kittanning, on very high land, whence it stretches in an undulating line S. to Buffalo Creek, crossing the Worthington and Freeport Road almost 3½ miles from Worthington. The dip towards Kittanning is from 3 to 5 degrees. Beyond the fifth axis, upon N.W. dips, the Elk-Lick Coal appears again, 12 miles N.W. of Nichol's Furnace, and at Sugar Creek Furnace, as already described. Two or three miles below Kittanning, on the E. side of the river, the Freeport Limestone is seen coming down to a much lower level. It is here about 10 feet thick. It is of a light-blue or dove colour, fine-grained, and homogeneous. On the opposite side of the river it is better exposed in a ravine three-fourths of a mile below the town, having beneath it a layer of iron ore varying in thickness from 6 inches to 1 foot, and similar to that seen under the same bed at Alleghany Furnace. A little farther down we have the following section:—

Shale; Upper Freeport Coal; Shale, 10 feet. Freeport Limestone, 6 feet; Shale and yellow Sandstone, with vegetable remains, 40 to 50 feet; Blue Shale in the river, 18 feet.

The Lower Freeport Coal was not seen, and probably does not belong to the above section. Half a mile lower down, the Upper Freeport Coal has been opened at about 70 feet above the river. This locality is 1½ miles above the mouth of Glade Run.

Back of the mill on Glade Run, on the Butler and Kittanning Turnpike, and a few feet above the level of the stream, is seen the *Lower Freeport Coal-bed*, from 3 to 3½ feet thick; roof, shale; floor, massive (Freeport ?) sandstone.

The *Lower Freeport Coal,* which outcrops on the high land S. of Red Bank Creek, upon the Olean Road, is not seen in the hills on each side of the mouth of Mahoning Creek, these not being high enough for it; but it appears again 1½ miles distant down the Alleghany River, in the highest hill-tops, and outcrops on the road to Waterson's Ferry, 5½ or 6 miles from Kittanning, and again 2 miles N. of Worthington. It arches over the fifth axis, often lying upon this in patches immediately after passing Buffalo Creek; whereas the Upper Freeport Coal continues to outcrop on each side of the axis for 6 miles farther S.W. It may be seen 18 inches thick, on the hill-side over the Worthington Turnpike, upon the Western bank of Buffalo Creek. Here huge blocks of Freeport Sandstone beneath the coal-bed cover the slopes. Below the latter the Kittanning Coal-bed has been mined for the Buffalo furnace-engine, and yields 3½ feet of pure non-pyritous coal; roof and floor, ferriferous shales.

The Ferriferous Limestone is here 15 feet thick, blue and solid; above it is the ore-bed of the furnace, accompanied by very little buhrstone. The Tionesta Sandstone appears in the bed of the stream, with ferriferous shales above, and the Clarion Coal, here workable.

Three and a half miles S.E. of Buffalo Furnace, the Ferriferous Limestone and adjacent coals are brought up by the fifth axis, where it crosses Rough Run, half a mile above Haylett's mill, or 1½ miles above its mouth. Here the hills rise more than 200 feet from the water-level, and show the following section at their base:—

Shale; *Ferriferous Limestone,* 17 feet; Shale, 20 feet; *Clarion Coal,* 4½ feet; Shale, &c., 35 feet to water-level.

The Kittanning Coal is opened higher up on Long's Run, three-quarters of a mile N.E. of Haylett's mill. The dip is 5° a little S. of E.

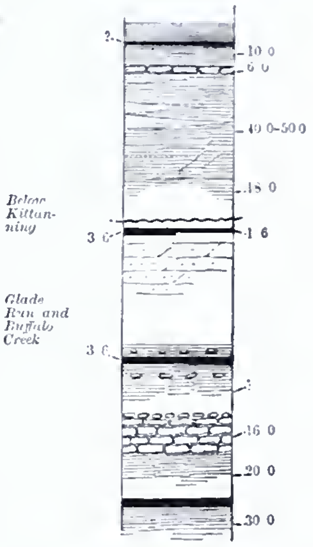


FIG. 456.—Shady Run.

Three or four miles S. of Worthington, a small run gives the following series:—

Slaty Sandstone, 10 feet exposed in layers, 30 inches thick; Soft black Shale (Upper Freeport ?); *Coal,* 3 feet.

The establishment of Winfield Furnace has caused a tolerably full development of the strata upon the waters of Long and Rough Run. Besides the Clarion and Kittanning coal-beds, with the intervening strata embraced in our section, the Upper Freeport Coal, 3 feet thick, underlaid by its limestone, has been opened. From the associated fire-clay beneath this bed is derived the brown calcareous ore extensively used at Winfield Furnace for the smelting of iron. It is sometimes developed to a thickness of 4 feet, though its available thickness is not so great. We here find conditions closely analogous to those previously described at Brady's Bend.

At *Freeport,* one mile below the mouth of the Kiskiminetas, the following section was obtained (see Fig. 457), and illustrates what will hereafter be said of the line of the Alleghany River to Pittsburg:—

Green and grey micaceous Slate and Sandstone, somewhat calcareous, 36.1 feet; Blue Slate at top, brown Slate at bottom; Micaceous Sandstone; also dark-blue Calc Slates, containing a few stems of Encrinites.

Coal, 8 to 10 inches. Interval, 10 feet of green Slate, at bottom, 33 feet.

Coal, 18 inches, with few inches of rich slate above; Shale above, sandstone below, 15 feet; Sandstone, massive conglomerate at bottom, with nodular iron-ore in scattered balls or regular bands 2 to 4 inches thick, 23 feet.

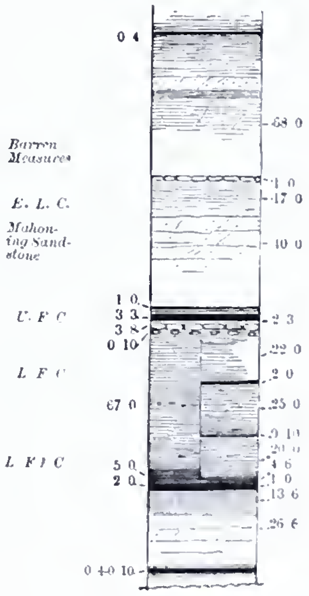


FIG. 457.—Freeport.

Coal, 4 inches; Roof, ferruginous Shale, Encrinites numerous, and bivalves; floor, blackish ferriferous Shale, passing into slaty sandstone, 12 feet; Shale, 9 feet; Sandstone Slate, 7 feet; Blue-black semi-bituminous crumbling Slate, 4 feet; Green argillaceous Slate, 26 feet; Calc Shale, 6 inches; Green Slate, 7 feet; Slate, 3 feet.

Limestone, Non-Fossiliferous, greyish blue, 1 foot; Grey and green Slate, 17 feet; Greenish-grey micaceous Sandstone, flaggy structure, 40 feet; Bituminous Shale, 1 foot; Bluish crumbling black Slate, 3 inches.

Upper Freeport Coal, 3.25 feet; Fire-clay and Shale, 2½ feet; Limestone, brecciated in aspect, greyish-*blue*, 3.8 feet; Nodular Limestone in shale, 10 inches; Olive Slates, 6.3 feet; Sandstone, 1 foot; Brown and olive Shales, 10.3 feet; Slaty sandstone, 1 foot; Brown Shales, 5 feet; Olive Shale, ferriferous, 4 feet; Brown Shale, 23 feet; Blue Slate, 12 feet.

Lower Freeport Bituminous Shale and Coal interlaid, 5½ feet; Shale, 2½ feet; Bituminous Shale, with carbonised stems, leaves, &c., 6 inches; *Coal*, 2 feet; Arenaceous Slate, ferriferous, and some sandstone, 13.5 feet; *Freeport Sandstone*, white, massive, lower part slaty, 26.5 feet.

Coal, 4 to 10 inches, divided by slate; Blue Slate, with fossil plants, 2½ feet. Interval 6 feet, to the river water-level.

It is probable that, if the hills had been a few feet higher, the Fossiliferous Limestone at water-level at Pittsburg would have been noticed in this section.

The lower part of the above section was taken opposite Freeport, above the ferry; the upper part a little higher up the river, near the old salt-works.

On Buffalo Creek, back of Freeport, two small coal-beds, not included in the section, have been ascertained to exist. The first of these, 2 feet thick, is 26 feet below the main upper coal; the second, 10 inches in thickness, is found 25 feet lower. Below this, about 20 feet, the bituminous-shale stratum of the section is now wrought for the extraction of oil. Of this material, which may properly be termed slaty cannel-coal, there is between 5 and 6 feet in two benches; the lower, sometimes subdivided, 4 feet 7 inches, the upper 1 or 2 feet in thickness. Immediately beneath this reposes a bed of dirty bituminous coal not exceeding 1½ feet thick. Both this slaty cannel stratum and the measures beneath are of exceedingly variable dimensions. The underlying sandstone, at one place 15 feet thick, at others exceeds 30; while in some wells sunk by Messrs Berg and Gillespie in pursuit of the cannel bed, they discovered in lieu thereof only ordinary black shale filled with vegetable impressions.

On the lands of Messrs Stuart and Dodd, upon the E. side of the river below the mouth of the Kiskiminetas, the slaty cannel-coal is separated from the bright bituminous bed by from 6 to 8 feet of slate. The cannel stratum averages 5 feet in thickness. The Freeport Sandstone beneath forms massive ledges along the railroad. On the E. side of the river the coals are at a higher level than on Buffalo Creek, owing to a local rise in the strata, but there can be no difficulty in identification.

A proximate analysis of Dodd's cannel-coal, by Dr Alter of Freeport, developed 34 per cent of volatile matter. From 22 lb. of the coal he obtained 33 ounces of crude oil, a gallon of which yielded one ounce of paraffine, besides coal-tar, and the lighter oils, benzole, &c.

On the Kiskiminetas, 1½ miles above its mouth, are fine exposures of the *Freeport Sandstone*, dipping both W. and N. (falsely bedded, perhaps?)

Two and a half miles above its mouth, the Upper Freeport Coal is about 108 feet above the canal, due E., and 25 feet higher than at Freeport.

At Ottuman's and Lochran's salt-works the Freeport Sandstone has passed the fourth axis, and descended below water-level, dipping S.E. This is 4 miles above the mouth of the stream. At the last-mentioned works the *Upper Freeport Coal* is 69 feet above the canal, all the strata below it being shales. At the canal-level are (Lower Freeport ?) black slates, from 4 to 5 feet thick. This mass of shales dips up river rapidly, and at the same time changes into sandstone beds still interstratified with shales.

At Leechburg, 5¼ miles above the mouth of the Kiskiminetas, above which is a gentle undulation of the strata, the following section of the rocks (see Fig. 458) was obtained at the quarries :—

Sandstone and Shale, 14 feet; Shale, 16 feet. *Upper Freeport Coal*, 4¼ feet, 63 feet above slack-water; Blue-black Shale, 14 inches; Light Shale, 6 inches; *Coal*, 4 inches; Light Shale, 14 inches; Iron Ore, 3 inches. *Freeport Limestone*, 1 foot; Calc Slate, shale, 3 feet; Shale and large chunks of Limestone, 4⅓ feet; *Limestone*, 32 inches; Shale, with calcareous nodules and flags, 5 feet; Calcareous Shales, 6 feet 8 inches; Shale, sandstone, &c., 3 feet; Sandstone, 1 foot; Shales, a little bituminous, 1 foot; Blue Ferriferous Shale, 7 feet; Shale and Sandstone, 6 feet. *Massive Freeport Sandstone*, 42 feet. *Lower Freeport Coal, interstratified with Slate*, 4 feet.

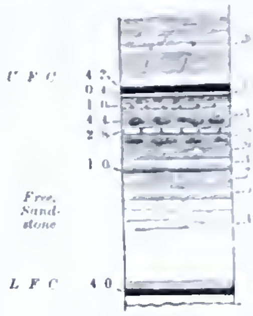


FIG. 458.—Leechburg.

The Freeport Sandstone, near the water's edge, is a fine quartzose conglomerate, containing vegetable impressions and pebbles of nodular carbonate of iron, of all sizes, and so numerous in places as to compose the whole mass of the rock for a thickness of 6, 8, or even 10 inches. A slip appears to combine with the original oblique bedding of the sandstone, to express to the eye of the spectator an unconformity of stratification at the upper limit of the sandstone; and upon its apparently upheaved edges rest the calcareous slates and coal above, as in the annexed woodcut (Fig. 459). Something similar may be observed elsewhere along the Kiskiminetas, as at a point 7 miles below Saltzburg.

At the salt-works, half a mile from Leechburg toward Warren, the *Upper Freeport Coal* is 62½ feet above slack-water, or 63½ feet above the level at Freeport. It is 3½ feet thick, covered by 16 feet of shale. It sinks to an altitude of 50 feet for the next 2 miles up the river, and is there 3 feet 3 inches thick, covered by 2 feet of black slate, and this by 8 feet of sandstone.

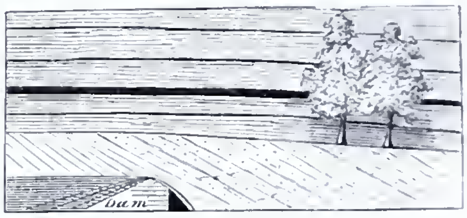


FIG. 459.

A fourth of a mile below this point the following section exhibits the coal at a much lower elevation:—

Shale, 6 feet; *Upper Freeport Coal*, 3 feet 3 inches; Shale, 22 inches; *Coal*, 7 inches; Shale, 3 feet. *Freeport Limestone, blue*, 2 feet; Soft Sandstone, 1 foot; Shale, 17 feet to bed of Pine Run, not much above slack-water.

This appears to be about on the middle line of the Fourth Basin. In the middle of the basin both coal and limestone seem thin and irregular. Approaching Warren within 3½ miles, the Lower Freeport Coal (?) is seen, measuring 2 feet 10 inches, good, with a lower slaty member 8 inches thick; roof, black slate, 2½ feet thick. Within 3 feet of its floor is the top of a solid sandstone stratum, 20 feet in thickness, extending down to water-level. Two miles and three-fourths below Warren, the following section (Fig. 460) was obtained:—

Shale, &c.; Shale, 14 feet; Black Slate, 2 feet; *Upper Freeport Coal*, 2 feet 10 inches (61 feet above Lower Freeport Coal); Shale, &c., no exposures, 14 feet; Olive Ferriferous Shale and Sandstone, 20 to 25 feet; Sandstone, 18 feet; *Coal*, 1½ inches; Shale, a few inches; Sandstone, 5 feet. *Lower Freeport Coal*, bituminous slate, 2 feet, 10 feet above slack-water.

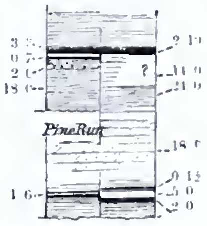


FIG. 460.—Below Warren.

It is divided at a short distance from this point into two members by 1½ feet of shale. The coal is highly pyritous, and a little farther on, up the river, appears thus:—

Coal in thin flakes, 1½ inches; Grey Shale, 1½ inches; *Pyritous Coal*, 26 inches; Shale, 4 feet.

Below Warren the following section (Fig. 461) was levelled:—

Greenish and brown Sandstone and slate, hill-tops, 21 feet; Olive Slate, 18 feet; Interval, 67 feet; Terrace interval, 45 feet; Green Sandstone, 1½ feet; Olive-green Slates, 36 feet. *Limestone Fragments*, greyish-blue non-fossiliferous, from 12 to 18 inches in diameter; Olive Slates, 30 feet; Blue Slate, sometimes containing bivalve and flat spiral shells, resembling those of the "black limestone strata," 35 feet below; Yellow slaty Sandstone, 6 feet; Bright yellow Shale, 8½ feet; Green Shale, 4 feet. *Green Fossiliferous Argillaceous Limestone*, 19 inches; Clay and Shale, 11 feet; Light-coloured Shale, 5 feet; Blue Shale, 16 feet; Blue Slate, 6 feet; Blue fossiliferous Slate, 2 feet. *Dark-blue Limestone, nodular*, 4 inches; *Compact*, full of Encrinites, and univalve and bivalve shells, 4 inches; Blue ferriferous fossil Slates, 4 feet; Brown Sandstone, vegetable impressions, 3 feet; Shales, ferriferous above, bituminous below, almost coal for 6 inches, 7 feet; Slate, 17 feet; Sandstone, thin-bedded, 7 feet; Massive, 8 feet; Slaty, 4 feet; Shale, greenish, 12 feet; Olive, 11½ feet. *Upper Freeport Coal*, 2 feet at outcrop, 15 inches when driven in; interval, 11 feet. *Freeport Limestone, nodular*, 12 inches; Shale, 12 (?) feet; Sandstone, grey, 15½ feet; Brown Shale, 17 feet; Black Slate, 2 feet. *Lower Freeport Coal*, 4 feet; 16½ feet above bed of river.

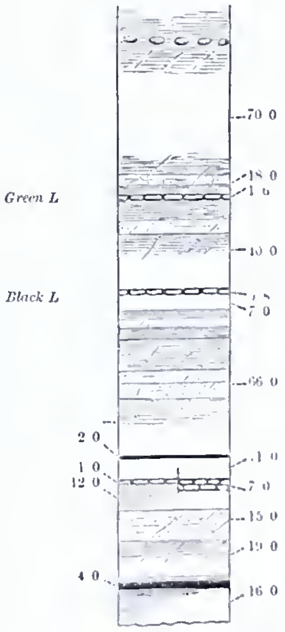


FIG. 461.—Warren.

Fragments of the so-called Freeport Limestone were burned by Mr Owen for lime, but without success. The dark-blue limestone above, roofed and floored with black slate, contains fossils easily obtained, and so characteristic of this part of the Barren Measures as to be highly important in defining the position of the Freeport Coal and limestone beds below. The stratum is a true geological landmark over a wide extent of Indiana and Armstrong counties. Here it occurs but 73½ feet above the *Upper Freeport Coal;* elsewhere the distance is increased. The interval above it also, up to the green limestone stratum, is less here than its average, being only 40 feet. The green limestone stratum is full of fossils, but has no great variety of species. Above this are barren exposures for 128 feet, and 151 feet more to the surface of the upland. In this last space some of the non-fossiliferous limestones below the Pittsburg Coal-bed should appear.

Three-fourths of a mile above Warren, the Freeport Limestone, 7½ feet exposed, is quarried on the N. side of the canal, 57 feet above water-level, pale in colour and highly silicious: the coal is not seen.

Below the Four-mile Slackwater Dam are several coal-openings, one of them upon the Kittanning Coal-bed, 3½ feet thick. The strata rise rapidly W. Just below the dam, and 3 miles above Warren, the following section (see Fig. 462) was obtained, in which, for the first time in ascending the Kiskiminetas, the Kittanning Coal appears:—

Hill-top, more than a hundred feet above, 8 feet of sandstone roofing the *Upper Freeport Coal* and *Freeport Limestone.* Interval hence downwards roughly estimated at 230 feet to the *Ferriferous Limestone,* 3½ feet exposed, elsewhere 7 feet; Brown Shale, 30 feet; Sandstone, 2 feet; Greenish Shale, 12 feet; Grey slaty Sandstone, 5 feet. *Iron Ore,* 5 inches; Shale, silicious, 7 inches. *Iron Ore,* 3 inches; Shale, 5 feet. *Iron Ore,* 2 inches; Shale, 1 foot; Argillaceous Sandstone, 10 inches. *Iron Ore, nodular,* 5 inches; Black Slate, 3 feet; Blue Shale, 7 feet. *Brookville* (?) *Coal,* 12 inches; Blue Shale, 4 feet; Black Slate, 18 inches, exposed at water-level.

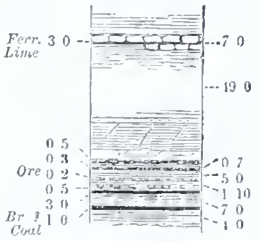


FIG. 462.—Three miles above Warren.

The third axis crosses perhaps a half-mile higher up the dam. The Ferriferous Limestone at Johnson's Salt-works is 55 feet above slack-water, 7 feet thick, and contains several species of fossil shells, a Terebratula, &c.

Just below the Salt-work Company's store, 2 miles above the dam, was obtained the following section (Fig. 463):—

From the top of the hill downwards, including 10 feet of shale just above the coal, 138 feet, estimated. *Elk-Lick* (?) *Coal,* 5 feet; Interval, 42 feet. Massive (Mahoning ?) Sandstone, 20 to 25 feet (bottom 115.7 feet above the Kittanning Coal). (*Freeport Limestone* not observed here, but a short distance up the river seen under Mahoning Sandstone, 3 feet thick.) Sandstone, thinly stratified, 77½ feet; Slate, &c., 6 feet; Shale, 29 feet. *Kittanning Coal,* 3 feet 9 inches; Shale (?) 18 feet; Sandstone, 7 feet; Shale, 8½ feet. *Ferriferous Limestone,* 6½ feet; Sandstone, 12 inches; *Iron Ore,* calcareous, fossiliferous, hard, 3 inches; Blue Shale, 10 feet. *Clarion Coal,* 1 foot; Blue Shale, 12 inches; Light-yellow Shale, 18 inches; *Coal,* 16 inches, 17 feet above water.

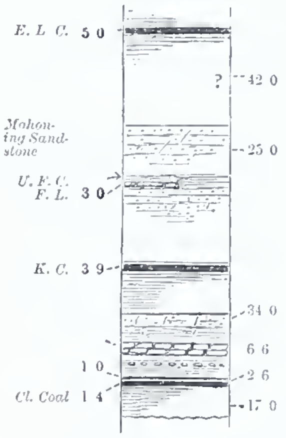


FIG. 463.—Four and a half miles above Warren.

It is remarkable that the lower coal-bed dips so steeply into the hill that it cannot be drained by the gangway, while the upper coal is not at all open to that inconvenience. This excess of dip characterises the lower strata in the hill.

The Ferriferous Limestone goes under the river-bed near the Salt Company's Store, the Kittanning Coal being at the level of the tow-path. The outcrop of the upper coal is observed rapidly descending E. up the river. Below the upper dam the Freeport Limestone is seen, 7 feet thick; and again, just below the dam and nearly on a level with the tow-path, where it is thin and nodular; the Upper Freeport Coal being absent or easily overlooked.

The middle line of the third sub-trough of the Third Basin crosses this upper slack-water (3 miles long) at about the middle of its length, and exhibits a very high series of rocks. The following section (Fig. 464) was made 3½ miles below Saltzburg:—

Soil, 7 feet; Grey Sandstone, slightly micaceous, 36½ feet. *Coal*, 12 inches; *Black Slate*, 2½ feet; Black Slate, 8 feet; Olive Shale, 10 feet. *Limestone, nodular*, 4 inches; Olive Slate, &c., under cover, 42 feet. *Coal*, 12 inches; *Clay*, 5 feet. *Limestone*, 14 inches; Shale, 2 feet. *Limestone*, 16 inches; Clay, variegated calcareous nodules, 5 feet. *Sandstone*, white, massive, weathering cellular in parts, 33 feet; Blue Slate, 10 feet; Grey Shale, 7 feet. *Pittsburg Coal and Slate*—(*Coal*, 30 inches; Black Shale, 3 inches; *Coal*, 12 inches; Grey Shale, 8 inches; *Coal*, 3 feet; Bituminous Shale, 2 inches; *Coal*, 3 feet); in all, 10 feet 2 inches; Clay, 2 feet; Sandy Slate, 15 feet; Micaceous Sandstone, greenish-grey, 4 feet; Light-coloured Shale, passing into an impure limestone, 15 inches, floored with calcareous clay—in all, 3½ feet interval. Shales, 7 feet; Greenish Shale, 12½ feet. Limestone, blue, non-fossiliferous, 1½ feet; Nodular Clay-bed, 2 feet; Greenish sandy Slate, 4½ feet; Nodular Clay, 2 feet; Green Slate, 3½ feet; Sandstone, 1 foot. Limestone Nodules in top of olive shales, 22½ feet; Green Slate, &c., calcareous nodules, 8 feet; Grey Slate, with bluff cleavage, 13½ feet; Grey and Purple Shale, 5 feet; Sandstone, 12 inches; Greenish Shale, 5 feet. Interval down to the water-level, 153½ feet.

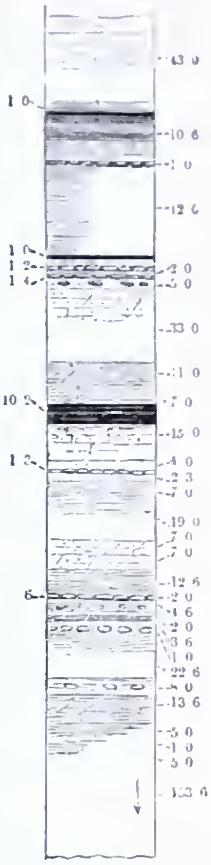


FIG. 464.—Three and a half miles below Saltzburg, on the Kiskiminetas.

Below this is the green Fossiliferous Limestone, as seen on the tow-path, passing under water-level at a point half a mile below. A small coal-bed underlies it at this place. At least 30 feet must be added to the last interval of 153½ feet, to bring the present section down to the green Fossiliferous Limestone, which will then lie about 350 feet below the Pittsburg Coal-bed. This remarkable stratum never seems to change its colour, and sometimes is nothing more than a mass of univalve shells cemented together by a fine mud. At Pittsburg it is seen 40 feet above the water, and 320 feet below the Pittsburg Coal-bed.

The Pittsburg Coal-bed, of this section, ranges Northward and Southward from the Kiskiminetas River, and towards Crooked Creek is underlaid by the same frosted-looking limestone seen at Pittsburg and elsewhere. The limestone stratum, 77 feet below the Pittsburg Coal, is a widely-persistent bed, as will hereafter be apparent; it is not quite *non-fossiliferous*, and has a brecciated aspect, although it is not fragmentary, but concretionary. It contains many of the minute fossils characteristic of the Freeport Limestone.

Towards Saltzburg the strata rise very slowly, the green Fossiliferous Limestone emerging from below the first lock at Saltzburg, where it consists of four bands, each between 1 and 2 feet thick, the whole measuring about 5 feet; and the representatives of the black Fossiliferous Limestone strata emerge in the first exposure above Saltzburg.

CHAPTER XXIII.

THIRD BASIN.—FIRST SUBDIVISION, ALONG THE CONEMAUGH: LOWER AND MIDDLE COAL-MEASURES.

THE first anticlinal axis crosses the Conemaugh a short distance below the spot where a small stream comes in from the S. below Blairsville. It barely elevates the Freeport Limestone to the level of the canal.

There are but two thin seams of coal exposed along the Conemaugh between Chestnut Ridge and the first sub-axis, belonging to the measures below the Pittsburg Seam. The lower is unimportant, the upper has been opened in but a few instances, as the country is supplied with fuel from the great Pittsburg Coal-bed above. The exposures along the river-banks from Blairsville to Chestnut Ridge are not good, and the difficulties attending the measurement of the strata are considerable. From the Pittsburg Seam down to the 60-feet interval actual measurements were made, but the thickness of the rocks below was only estimated.

Below Blairsville, the lower coal-beds are displayed: interrupted sections can there be made, but all the rocks exhibit a great tendency to variations of type from shale to sandstone, and *vice versâ*, within short distances, presenting perplexing difficulties to a general analysis of the contents of the basin.

Commencing with the lowest rock brought up by the first sub-axis below Blairsville, and proceeding down the river we have the following section (Fig. 465):—

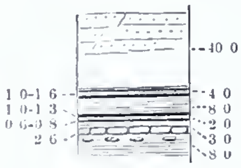


Fig. 465.

Blue Shale, 5 feet; Shales, 3 feet, with calcareous nodules; Irregular stratum of Limestone, 2½ feet; Blue Shale, 3 feet; Coal, from 6 to 8 inches; Dark-blue soft Shale, 2 feet; Coal, from 12 to 15 inches; Shale, 8 feet; Coal, from 12 to 18 inches; Blackish Shale with thin coal-seams, 4 feet. (This section is made 2 miles below Blairsville, in a cut in the canal.) Over all is a massive sandstone dipping gently with some undulations.

In the exposure, which is several hundred yards long, the rocks exhibit striking changes of character: thus, at one point the shale under the sandstone is 10 feet thick, but in a few rods becomes a sandstone, which rests immediately upon the coal. The shales between the coal-seams thicken and thin variously. At one place where this appearance presents itself, the coal seemingly terminates in the sandstone. Near the place where these disappear with a W. dip beneath the water-level, the massive sandstone, resting on the coal, changes wholly to shale for a thickness of 12 feet: the sandstone then presents a vertical wall, 40 or 50 feet thick, in coarse grey massive strata, with irregular lines of deposition along the canal.

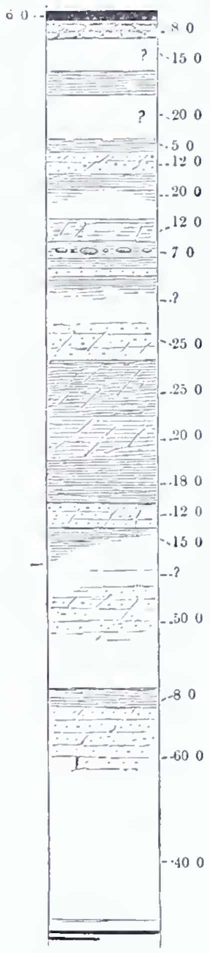


Fig. 466.—Opposite Blairsville.

This section finds no equivalent in the lower part of the section made above Blairsville; yet there is an interval of 30 feet in which it may find a place. The limestone may be the Freeport Limestone, as we find a locality a short distance up the Black Lick Creek where the Mahoning Sandstone appears, and over it grey slate 2 feet, and then slaty coal 18 inches. The dip is Westward.

There are frequent exposures of the middle series between the axis and Blairsville, of which the following is a compiled section (see Fig. 466); all the thicknesses were estimated by the eye, and collated as accurately as could be done.

It embraces nearly 400 feet of rocks, of which the upper one-third were observed opposite Blairsville; the middle third, 300 yards below the town, near the middle of the trough: the interval omitted must therefore be small.

Comparing this section with that made above Blairsville, nothing more than a general resemblance will be traced between them.

Second Subdivision.—The Conemaugh River takes a very irregular course across the second synclinal trough W. from Chestnut Ridge, affording frequent exposures. These present themselves in the order of the following section:—

Olive Shales, 80 feet; Black and brown Shales, 20 feet; Blue Shales, 50 feet; Olive Shales, 40 feet; Coal-bed, 18 inches, position unknown.

The summit of a high knob three-quarters of a mile below the mouth of Black Lick Creek gives this section:—

Yellow Shales, 13 feet; Red and blue Slates, with included calcareous nodules, 14 feet; Yellow Slates, silicious and shaly, 17 feet; Coarse grey Sandstone, strata much fissured, 16 feet; Dark olive Slates, 12 feet; Red Shale, 20 feet; Yellow sandy micaceous Slates, 30 feet—35 feet interval. Red Shale, 10 feet; Dark olive silicious Slate, 20 feet; Dark olive, bluish, sometimes fossiliferous Slates, 40 feet; Brownish-red and yellow Slates, 25 feet; Coarse grey Sandstone, with shale in irregular masses, 25 feet; Grey micaceous Sandstone, 200 yards below the former by the course of the river, 20 feet—interval, no exposures for 200 yards farther. Yellow, olive, and brown Shale with red layers, 30 feet; the Mahoning Sandstone; finally, the small coal-seams described in connection with the first sub-axis.

Lower rocks are exposed in the neighbourhood of Livermore at water-level. Three-quarters of a mile above Livermore there is a fine natural section of the olive shales (40 feet), and blue shales (50 feet), the latter falling into square gravel, and thin scales and splinters. A seeming displacement of the strata appears on two sides of a deep sharp cut. A micaceous sandstone caps the shales a quarter of a mile below Livermore, where the rocks are nearly horizontal; and still higher shales form a high wall for three-quarters of a mile lower down the river:

these are the 80 feet of olive shales at the top of the section, which continue exposed until near the tunnel, where a coarse sandstone band is also seen. From the W. end of the tunnel the river courses along the strike of the rocks, exposing no different strata for the distance of a mile, when it turns and cuts the second sub-axis, the olive slates forming high hills on each side.*

Thus there are estimated to be 500 feet of strata in vertical thickness above the thin coal-seams (or Upper Freeport Coal, as they no doubt are), with no indication of the Pittsburg Coal-bed, which does not make its appearance until we pursue the central line of this sub-basin Southward for several miles from the river, when it is found cropping out upon the highest hill-tops. The measures must therefore have received an enormous expansion (as described in the preliminary general description), compared with their condition in, and Eastward of, the second axis or Chestnut Ridge. That this expansion has taken place in the lower members of the Barren Measures, is apparent from the fact that the great mass of shales have no counterparts along the base of Chestnut Ridge.

The centre of the trough is in the neighbourhood of the tunnel, and there is seen a little Westward from the W. end of the tunnel, on a little run, and only elevated a few feet above the level of the river-bed, a band of black and somewhat concretionary limestone from 4 to 6 inches in thickness, containing fossils. The fossils, however, are much more abundant in a band of black ferruginous slate immediately below the limestone; they are mostly Bellerophons, with a large species of Ammonite, and a few other molluscs. Black bituminous slate is seen still lower in the bed of the river, and 15 or 20 feet of the same also overlies the limestone: green and mottled slate succeeds above this for 35 or 40 feet. These strata are doubtless the "Black Limestone layers" occurring at about their proper distance beneath the Pittsburg Coal, but having all the vastly-expanded shales of the lower Barren Measures beneath them.

There is said to have been once discovered in the river-bed, below Livermore, a somewhat thick stratum of coal. If such has been the fact, the bed must be regarded as one of the small seams traversing the Barren Measures at various altitudes, and locally expanded in its thickness. Two miles from the W. end of the tunnel, the Saltzburg Coal-seam (Upper Freeport Coal) emerges with quite a steep Eastern dip from below the water. At Farelan's Salt-works, 400 yards below where it first emerges, it is 3 feet thick. At Mr Porter's it is 60 feet above the water-level, and begins to descend Westward: it dips beneath the water again a short distance below Mr Stewart's salt-well, where the river and canal sweep round the high bluff a mile and three-fourths above Saltzburg; the distance between its points of appearance and disappearance being between 3 and 4 miles.

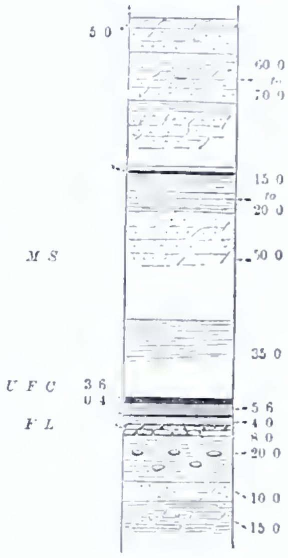


FIG. 467.—Saltzburg.

A section of the rocks observed along the Conemaugh at and above the point where the Upper Freeport Coal disappears, is annexed (Fig. 467), and is compared with one obtained upon the Loyalhanna, also near the axis, and shortly to be described. Beginning from above it presents:—

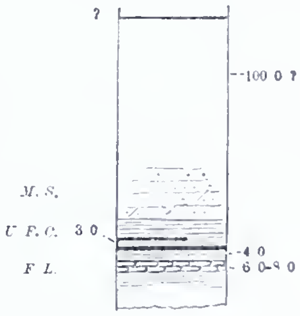


FIG. 468.—Loyalhanna.

Fossiliferous green Sandstone, 5 feet. (The debris of this rock occurs along the bank below, at the outcrop of the coal-seam below the canal-lock: it is in place N.W. of the lock). Sandstone, interstratified with compact shale, 60 or 70 feet. Bituminous Slate, or slaty coal, 4 to 6 inches, and 100 to 150 feet above the canal-level; Shale and Sandstone, 15 or 20 feet; Sandstone, 20 to 30 feet; by another section, 50 feet. This forms the high ledge of rocks above Saltzburg. Brown and olive shale, 35 feet. *Upper Freeport Coal*, 3 feet to 3 feet 8 inches; Black Shale, 1½ feet; Yellow Shale, 4 feet; *Coal*, 4 inches; Yellow and blue Shale, 4 feet. *Freeport Limestone* in irregular layers, and with some nodules of iron ore, 8 feet—in another place, only $1\frac{1}{2}$ feet; Soft Shale, containing calcareous nodules, 20 feet; Grey micaceous Sandstone, 10 feet; Sandstone and yellow Shale, 15 feet.

---

* This second axis is best located three-fourths of a mile below the Little Run, marked Elder's Run upon the State Map, the name of which, however, is now appropriated to another run flowing into the Conemaugh at Livermore, and between 4 and 5 miles below Blairsville.

In these exposures we find, in a distance of 200 yards, a complete conversion of a stratum of shale into massive sandstone, again into shale, and again into sandstone, thinly stratified and of quite a different colour. The Great (Mahoning) Sandstone, above the Upper Freeport Coal, forms a high wall or cliff along the river, below the mouth of the Loyalhanna. Along that creek, and also above its mouth, it forms the precipitous base of the hills along both sides of its valley, for a number of miles, as it winds its transverse course across the second sub-axis, through which it cuts as deeply as the Conemaugh.

The Upper Freeport Coal rises from the creek one-fourth of a mile below M^c^Guide's Mill, 2 miles up the creek. It is here 3 feet thick, and under it are 4 feet of black slate, supported by thin layers of limestone, and full of the most beautiful fossil-plants. It is 30 feet above the water 400 yards higher up the creek, and 45 feet above the water at an opening half a mile above the mill, and 3 or $3\frac{1}{2}$ feet thick. One mile higher, it is 3 feet 8 inches thick, with bluish olive slate above. The Ferriferous Limestone is seen below, from 6 to 8 feet thick. A fourth of a mile still farther, the coal-bed sinks beneath water-level; that is, about 4 miles above the mouth of the creek.

At the bend of the creek, opposite Mr Bovard's house, there appears a seam of coal, a few inches thick, in the blue shales under the Mahoning Sandstone. Below Donolley's Mill the Mahoning Sandstone is a thinly-laminated micaceous sandstone of a grey colour, sometimes filling the bed of the stream with its debris.

Frequent exposures of the rocks of the Barren Measures are made along the Loyalhanna, as at New Alexandria, from a portion of the series, perhaps 250 feet beneath the Pittsburg Seam downwards, but consisting merely of a series of sandstones and shales of different textures and colours. Their aggregate thickness may be 250 feet. A thin coal-seam, perhaps 100 feet above the Mahoning Sandstone, was observed among them.

Half a mile from Snodgrass's Mill, the Pittsburg Seam makes its appearance at an elevation of 150 feet above the creek. Between this point and New Alexandria there are frequent exposures of the measures under the Pittsburg Coal, consisting of sandstones, slates, and shales, as on the W. side of the second sub-axis. Starting from a level, perhaps 250 feet below that of the Pittsburg Coal, we have a section composed of the following strata:—

Black and brown Shale, and over this micaceous sandstone, 15 feet; Yellowish-blue Limestone, 2 feet; Yellow Shale, with calcareous nodules, 3 feet; Blue and yellow Sandstone, in rough lumpy strata, mixed with shale; fissures filled with shale, containing fossils, 10 feet.

Grey Sandstone, 35 feet; Blue and red Shale, 12 feet; Impure yellowish Limestone, weathering light yellow, and falling into rough angular fragments; slaty layers, 6 feet; Blue and red Shale, 8 feet; Interval, 20 feet.

Grey rough Sandstone, 16 feet; Yellowish Slate and blue Shale, 15 feet; Dark-blue Slate, with silicious layers, thinly-laminated and micaceous, 35 feet; Soft olive, yellow, and blue Shale, 25 feet; Blue Slate; upper part Sandstone, lower part argillaceous, with nodules of carbonate of iron and carbonate of lime. *Coal*, 12 or 18 inches.

Blue Shale, full of calcareous and ferriferous nodules, 12 feet; Coarse brown Sandstone, near Craig's Mill, 25 feet.

Farther up the creek, and lower in the series than the rocks of this section, two thin coal-seams have been opened at Brady's Mill; they are the lowest rocks visible where the Loyalhanna crosses the first sub-axis above New Alexandria; their vertical depth below the Pittsburg Coal may be estimated at perhaps 450 feet. This returns us, by the way of the Loyalhanna, to the first sub-basin and the foot of Chestnut Ridge. This is so much deeper than the second sub-basin, that the Pittsburg Coal-bed reaches and passes under the bed of Loyalhanna Creek. The exposures along the creek flowing out of the gap of Chestnut Ridge towards the middle of the trough, or above Youngstown, exhibit the usual variable mass of sandstones and shales composing the Barren Measures, hardly to be identified at any two points, however close; and also some coal-beds, to be hereafter described.

CHAPTER XXIV.

1. LOWER ROCKS OF THE FIRST SUB-BASIN, OF THE THIRD BASIN, BETWEEN THE LOYALHANNA AND THE CONEMAUGH, ALONG THE BASE OF CHESTNUT RIDGE.

Denuding agencies have acted with energy upon the outcrop of the Upper Barren Measures along the flank of Chestnut Ridge.

M^cGee's Run occupies the line of greatest denudation, having a ridge of sandstone strata containing the smaller lower coal-seams on the right, and another ridge, with the Pittsburg Coal-seam outcropping at its base, or on its side, to the left. The former generally exhibits a range of elevations blending at intervals with Chestnut Ridge, but standing out as bold knobs at all the transverse cuts or gaps. Sometimes it is rather a regular terrace than a distinct hill.

The flat valley of M^cGee's Run gradually narrows and heads up towards the S., as does that of the corresponding run flowing into the Loyalhanna. The central or Western ridge containing the Pittsburg Coal becomes higher, and exhibits less the effects of denudation. In the space between the heads of the two streams are frequent exposures of the Barren Measures (shales and sandstones). Some of these are persistent—as, for instance, the red and variegated shale-bands of the sections, and some of the larger sandstone strata. The lower coal-beds have been but little explored. A three-feet bed is opened at about a fourth of a mile from Ray's Mill; near this was seen a small coal-outcrop, with 20 feet of brownish shale above it. These are perhaps the Upper and Lower Freeport Coals. The notch at Ray's Mill is a gorge or cutting down into the Umbral red shales.

Approaching the Loyalhanna, no exposures of the lower coals are afforded that could suffice for an accurate section, until within a short distance of that stream where the hills are higher, and approach nearer to the Chestnut Ridge than on the Conemaugh.

Coal-Beds of Loyalhanna Creek.—The 5½-feet coal, the lowest in the series, is opened a short distance N. of Loyalhanna Creek, on the side of the ridge, and was judged to overlie the Seral conglomerate by perhaps 30 feet. The quality of the coal is good, though somewhat soft and a little slaty. Immediately upon the coal at this point reposes a coarse-grained white sandstone, 5 feet of which is exposed.

A few hundred yards from this opening towards the creek is an exposure of a 20-inch coal-seam, wrought, and yielding an excellent coal. The relative position of these two openings or beds was extremely difficult to determine. Two thin seams are exposed in the first depression at the base of the ridge, 1 mile N. of the creek.

The creek gives numerous good exposures of the rocks above these coal-beds, many of which are olive slates. A blank interval of 140 feet in the sequence, judging from surface fragments, consists of olive-coloured rocks, as does much of the space below the underlying 40-feet sandstone. But there does not seem ground for supposing the presence here of full equivalents of the enormous exposures of olive shales in the second sub-basin on the Conemaugh. As we go farther S., we find still fewer rocks of this colour. Exposures of the upper portions of the Barren Measures are rare. The 40-feet thick sandstone (Mahoning Sandstone) here forms quite high hills at the base of Chestnut Ridge. As we enter the gap, fine cliffs of the conglomerate are seen; then the Umbral red shales; and finally, at the axis, the Vespertine blue sandstone layers.

Coal-Beds of Loyalhanna at the First Sub-axis.—On the W. side of the First Basin along the Loyalhanna, the rocks of the Barren Measures are sandstones and shales, with a few calcareous layers, but no regular limestone bands. One of the lower coal-seams, 2½ feet thick, with bluish shale and sandstone over it, is exposed at a spot 1½ miles above Brady's Mill in the creek.

At Brady's Mill the rocks dip West (from the first sub-axis into the second sub-basin), and expose two coal-seams between 2 and 3 feet thick, and between them 25 feet of olive and grey slate, with silicious layers. Above the upper coal are yellow shale and coarse sandstone in thick strata. The coal, 1½ miles above Brady's Mill, is probably one of the two coal-beds opened half a mile from Craig's Mill.

2. LOWER ROCKS SOUTH OF THE LOYALHANNA, ALONG CHESTNUT RIDGE.

Denudation has acted along Nine-mile Run, as along McGee's Run, causing occasional exposures of the Barren Measure shales and sandstones. At none of the notches in the ridge are the lower coal-seams exposed for some distance to the S. of the Loyalhanna; Jacob's Creek is the first that cuts deep enough to bring their outcrops to the day. Of course, however, their E. outcrops run continuously among the sandstones high up Chestnut Ridge.

A similar ridge to that before described ranges along the W. side of the valley of the run, with the outcrop of the Pittsburg Seam along its base. The valley narrows in like manner as it heads up S., and the W. hills, gradually approaching Chestnut Ridge, finally form spurs or transverse elevations connecting it with the central height of the trough.

Between the waters of the Loyalhanna and those of Jacob's Creek, one branch of the Big Sewickly takes its rise near the Chestnut Ridge, being separated from the main creek, and continuing so as far as Jacob's Creek, always having the Pittsburg Coal outcrop on the W. side of the continuous depression.

Coal-Beds on the Big Sewickly, First Sub-basin and Axis.—Sewickly Creek, at its head, affords but few exposures of the E. outcrop of the lower coal-beds and middle Barren Measures. Along its course, through the first sub-axis in the East-dipping rocks, are some fine exposures of sandstone; a thin coal-seam also appears near the middle of the series.

The coal-bed (Upper Freeport Coal), from 6 to 4 feet thick, rises from the water-level to cross the first sub-axis for a distance of 4½ or 5 miles from Chestnut Ridge, at Roof's lower mill. Here there are exposed with the coal 15 feet of micaceous sandstone, and some layers of blackish slate. The coal is 4 feet thick, and upon it lies a coarse sandstone. This coal-bed supplies with fuel all the salt-wells along the stream, and is no doubt the same with that which supplies the salt-works of the Conemaugh. Its coal is rich, solid, and free from iron and slate impurities, though it occasionally shows a thin seam or two of interstratified slate. If this be the Upper Freeport Coal, it may appear strange that the limestone beneath it, so largely developed on the Conemaugh, is not here found.

The Sewickly Valley holds its course for several miles along the anticlinal axis, winding from side to side of the arch described by the Upper Freeport Coal-bed, and allowing numerous gangways to be driven into it. The greatest elevation of its arch from the water-level is about 75 feet, and its distance along water-level is not above 1½ miles. At Irvin's salt-well, on the E. side of the creek, it yields 4 feet of good coal; and here there is so great an evolution of inflammable gas from the swampy spot in which the well was sunk, that the gas has been caught and used as fuel beneath the boilers. Below this, at the salt-well at the forks of the creek, the coal-bed is from 3½ to 5 feet in thickness, exhibiting great irregularities and disturbances. At one point of its outcrop it is wrinkled, and is but a few feet above water-level. A few hundred yards W. of this, there is a coal-opening much higher in the hill-side, which may possibly be another seam; if so, it would be the Elk-Lick Coal, as that is its proper position, supposing the assumption to be correct that these various openings are on the Upper Freeport Coal-bed. It is remarkable that no trace of such a higher bed of Elk-Lick Coal has been remarked elsewhere along the stream; these may therefore be merely an upthrow or local flexure of the coal-bed.

At the Mammoth Salt-works the bed is from 3½ to 4 feet in thickness, with sandstone on the coal; while at the mill, a short distance below this, it is 3 feet thick, with slate and sandstone above the coal. At Painter's salt-well, and at the crest of the axis, the bed is 72 feet above water-level, and 3 feet thick. Here there is seen a thin seam 52 feet beneath it, the interval being a coarse-grained thickly-stratified sandstone. At this Salt-well the evolution of gas is very great, and is employed as before stated. Here the hills are very high, and exhibit continuous outcroppings of the Barren Measures. At their base is the massive sandstone rock beneath the Upper Freeport Coal.

At the salt-well, one mile below the last, the bed, with thin slate interlayers, is only 2½ feet thick, thinning locally when followed into the hill. It is here 20 feet above the water, dipping W. Where opened at the salt-furnace opposite, it was not quite 2 feet thick. Openings up the hill-side to a great height above this bed, made in search of better ones, have developed some dark-coloured shales and two or three thin coal-seams.

The bed has been repeatedly opened with a gentle Eastern dip, perhaps three-quarters of a mile S.E. from the openings last mentioned, and found to be from 3½ to 5 feet thick, with sandstone roof.

Half a mile S.W. of this again, and on the opposite side of the high hill near Painter and Mitchell's lower well, this very irregular coal-bed exhibits the remarkable change of structure shown in the woodcut (Fig. 469), and that in the short distance of 300 yards, being at one place a single bed 3 feet thick, and at the other a double bed, divided by a layer of shale and sandstone, and each subdivision 3 feet thick. Farther on, in the same bank, a crush (section *a*) is visible: the upper bed is 3 feet thick; the two being separated by coarse sandstone.

A few yards from this we have *b*, the upper bed running out from 2 feet to nothing; and the undermost bed varying from 6 inches to 1 foot; *both shale and sandstone intervening.*

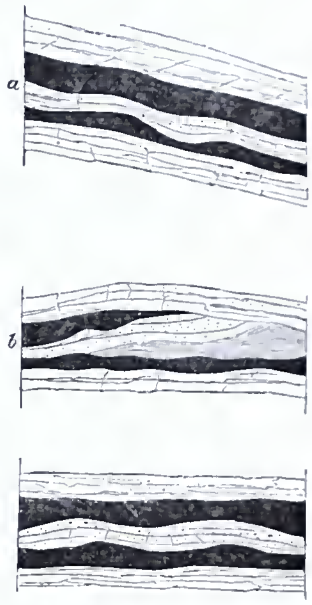


FIG. 469.

At another place, *c*, in the same opening we have the upper bed from 2½ feet to 5 inches thick, and the under one, 3 feet thick; with from 15 inches to 2 feet of sandstone intervening. A few rods off the whole bed has but 3 feet of coal; at another place it has 9 feet, with a few slate interlayers; these 9 feet shortly thin out to 1 foot. Some of the openings have been abandoned, the coal thinning out altogether. The roof shows numerous lumps and wrinkles, and is a confusedly deposited sandstone mixed with flakes of coal; stems of plants cross each other in all directions. The coal itself is highly bituminous, of a pure black colour, and separated into prisms. A boring, 300 yards from the openings last described, went down 100 feet, and touched no coal; whereas, had this bed, of which we are treating, proved at all consistent, it should have been struck by the boring 40 feet below the surface.

At Painter and Mitchell's lower salt-well, the E. bank of the Sewickly is 70 feet in height, being a deep escarpment of sandstones and shales; but no coal appears at the proper point—that is, 40 feet above the water—although it is wrought in the same strata only 70 yards to the E. To carry it below the creek-level an angle of 50° would be required, and that where the strata are almost horizontal; only a counter-dip of 45° could have projected its outcrop above the bank. The boring, 100 feet deep, also intervenes. The coal has therefore disappeared from this locality.

The Sewickly Creek flows along the axis for 1½ miles farther, and then W. across the second subdivision of the Third Basin. Mr Hurst's well is next in order to Painter and Mitchell's lower well, and perhaps three-fourths of a mile below it. The Upper Freeport Coal has not here been discovered in its proper position; coal is obtained from down the creek, where it sweeps to the W. Here it is exposed on the N. side of the creek bank, 4 feet in thickness, with a sandstone roof: the sandstone is coarse-grained, and full of vegetable impressions. The floor of the coal is a hard blue silicious slate. Old openings farther down the creek exhibit similar sections, the sandstone everywhere rolled, wrinkled, and confused.

At the bend of the stream is Harrol's coal-bank and salt-well, the latter 440 feet deep: a neighbouring well is 658 feet deep. The coal-seam is here from 4½ to 6 feet thick, subdivided by a thin band of blue slate at 18 inches from the floor. The top is sandstone, the floor hard silicious slate; the same character is found at Hurst's opening, 350 yards farther W. At D. Wortz's well, 400 yards farther on, the coal disappears beneath the creek. The sandstone often exhibits a thickness of 50 feet.

At Thompson, Turner, & Co.'s well, 1 mile S.E. of the creek at its bend, and 1 mile N. of the Mount Pleasant Turnpike, the bed averages 5 feet, but varies to 6½ feet. It contains here much sulphuret of iron, and has above it, as usual, coarse-grained irregularly-stratified sandstone, full of stems and leaves.

The following section of rocks intersected in boring the salt-well was kindly furnished by one of the proprietors; it commences at the surface of the ground, 25 feet below the coal-opening:—

Dark Slate, 39 feet; Sandstone, 42 feet; Light Slate, 24 feet. *Coal*, 3½ feet; Sandstone, 17 feet. Dark Slate, 48 feet; Sandstone, 19 feet. Soft Shale, 66 feet; Sandstone, 27 feet. *Slate* and *Coal*, 15 feet. Then "the Eighty-feet Rock" of the borers, a massive Sandstone, perhaps the Seral conglomerate, 112 feet. Black Slate, 16 feet. Red Slate, 50 feet. Sandstone to salt-water, 180 feet.

The 3½-feet Coal-bed is opened at other places between the Sewickly Creek and the Mount Pleasant Turnpike. It is 4½ feet thick at Hunter's old well, 10 feet above the level of the run; a band of pyritous slate runs through it 15 inches above the hard blue slate floor. At the turnpike, 5½ miles from Mount Pleasant, at the level of the run, the bed is 4½ feet thick, dipping gently E. The Great Mahoning Sandstone rests immediately on the coal. A thin slate-seam runs here also 18 inches above the floor. This is the most South-westerly exposure of the bed on the Sewickly waters: it appears again on Jacob's Creek.

The Sewickly runs hence W., exposing the whole series of the Barren Measures. Two very thin coal-seams occur in the series, dipping gently W. This gentle Westerly dip does not give place to an Easterly dip as we descend the creek, on account of the dying-out of the second sub-axis about 2 miles before it would have crossed the Sewickly. In consequence of this, a wide extent of country is here overspread by the Barren Measures; the Upper Freeport Coal being under water-level, and no dips being strong enough to bring it above the Pittsburg Coal. The terminus of the axis is marked by a few high knobs, but does not present so broken an aspect as does the face of the surrounding country; it has seemingly been more abraded by denuding forces. The hills slope gradually along this line to the rather wide depression or valley of the creek; while E. and S. of the creek, and also W., in the range of the Pittsburg Coal-bed, they rise more abruptly, and are higher. It is about 10 miles in a straight line from Chestnut Ridge to a high knob on the termination of this second sub-axis; and W. of this, to the point where the E. outcrop of the Pittsburg Seam crosses the Sewickly, it may be 2½ miles.

From the forks of the Robstown Road (5½ miles from Mount Pleasant), where the Upper Freeport Coal disappears in the run, as has been described, there are numerous exposures of the Barren Measures along the Robstown Road. Farther W., the red shales in the middle of the group frequently appear, though they were not seen along Sewickly Creek. A few small smut-lines are the only indications of the presence of coal, and these can be the outcrops of but very small beds. The Pittsburg Bed finally appears, and crosses the road a few miles W. of the forks.

3.—THIRD BASIN, FIRST SUBDIVISION, ALONG JACOB'S CREEK.

Jacob's Creek makes an irregular gap or notch in Chestnut Ridge, only deep enough to expose the silicious limestone strata at the base of the Umbral red-shale formation. Such exposures are seen at the arch of the axis a mile or two from the old furnace. Where the rocks begin to incline to the E. is an exposure of a few feet of soft ash-coloured shales; over these is a soft grey argillaceous limestone, full of fossils, 10 feet; over this, red shales, 12 feet; over these, grey micaceous sandstone, 20 feet. Supposing this to be the Seral conglomerate, search was made in the shales beneath for ore, but, with the exception of a few small nodules scattered through the shale, none was visible. It is probably to be found higher in the series. Farther down the Big Branch, abundant evidence of the presence of the Seral conglomerate is afforded by its fragments and exposures.

Upon a neighbouring head-branch of Jacob's Creek there is exposed a coarse-grained thickly-stratified sandstone about 60 feet in thickness; upon this are olive slates and blackish shales, with a coal-seam a few inches thick, among them; upon these lie blackish and olive shales, with sandstone interlayers, thickness unknown; over these, yellow shales, and a pure blue limestone stratum, 2½ or 3 feet thick. This mass of shales is about 20 feet in vertical thickness. Upon the limestone lie olive shales, 8 feet thick; then micaceous sandstone, 20 feet; then olive and yellow silicious slates, 30 feet.

For a space there are no exposures, and then occurs a coal-bed, 4 feet thick, of good soft coal, but containing sulphuret of iron in some quantity. Upon it lie dark olive shales, in some parts nearly black, and sometimes quite silicious, 65 feet exposed. We supposed this seam to be the 4-feet seam of Sewickly Creek, but remarked the striking absence of the Mahoning Sandstone above, and other irregularities consequent upon such an identification. A comparison with the section in Thompson, Turner, & Co.'s salt-well on the Sewickly, presented at the top of page 606, will guide us in assigning it its true position in the series as the Brookville (or Clarion) Coal-bed.

From this exposure the stream runs some distance along the strike of the rocks, but cuts them again across the dip a little above Lobinger's upper mill, exposing for three-fourths of a mile the sandstones and shales above the coal just described.

At the mill, another coal-bed, 4 feet thick, has been discovered near the mouth of a well sunk through it, and introduced into the section above. This is doubtless the Upper Freeport Coal of the salt-works.

A section was made past Lobinger's lower mill, crossing the outcrops of the lower coal-beds, and the outcrop of the Great Pittsburg Coal-bed, along the side of the central ridge of the basin. The following coal-beds were discovered in the side of the hills, and their distances asunder measured :—

First, Coal (Upper Freeport Coal), 3 feet ; above it, yellow Shale ; below it, at an interval of 43 feet, in which no rocks appeared in place, Coal, 3 feet ; below this, after another interval of concealed rocks of 136 feet, a third Coal-bed, 1 foot thick ; over it, coarse Sandstone, 12 feet exposed ; under it, blue and yellow Shales, with micaceous sandstone, 20 feet exposed.

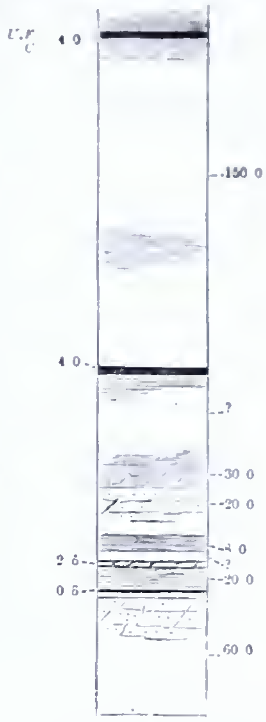


FIG. 470.—Jacob's Creek.

The uppermost of these seams exhibits a soft rich coal, separating into vertical prisms, and containing sulphuret of iron. It is divided by a thin slate, 1 foot from the floor, as seen in all the openings upon this bed along the Sewickly Creek. Its outcrop can be traced along the ridge to the E. of this locality. Above it, after an interval, is a small exposure of micaceous sandstone, and over this again the large sandstone stratum which forms the high rocks or spurs descending from Chestnut Ridge, between the head-runs of the creek. The space above this seam appears to be principally sandstone, interstratified with some shale. This is seen below the lower mill, on the South-facing point of the hill. The exposure is as follows :—

Sandstone, in thick coarse strata, 30 feet ; under this, olive and yellow, chiefly silicious Slates, 30 feet ; Micaceous Sandstone, 25 feet ; Olive, yellow, and blackish Slates, 20 feet ; Coal, brittle and hard, 14 inches ; Yellow Shale to the water-level.

Below the lower mill on the W., and higher in the series, is a sandstone stratum 50 feet thick, and under it a *coal-seam,* 6 inches thick, resting upon olive shales. Tracing the sandstone down the creek, a yellow slate, perhaps 20 feet in thickness, is seen to rest upon its top surface, and upon that a *coal-seam,* 3 feet thick, over which is a covering of yellow slate.

Thus we see that upon Jacob's Creek there are six coal-seams, from 6 inches to 3 feet thick, within a vertical section of perhaps 350 feet. If equal advantages for observation were everywhere afforded, no doubt similar results would be attainable along the whole flank of Chestnut Ridge. The uppermost 3-feet thick coal may be the Elk-Lick Coal-bed, or a locally enlarged exhibition of one of the small Barren-Measure coals. The Upper Freeport Coal has been worked by Mr Lobinger here, and also on Grass-Lick Run. The 3-feet coal-bed below it had there yielded 4 feet of coal.

Lower down the creek, exposures of the Barren Measures are numerous and unimportant, being chiefly of micaceous fine and coarse-grained sandstone and yellow slates. There is one exposure of the red-shale band of considerable thickness. At Mr A. Robinson's sawmill are seen a few thin strata of fossiliferous limestone enclosed in yellow slates. Still farther down the creek, and higher in the series, are found nodules of iron ore and of limestone in yellow shale. As we approach the part of the creek where the Pittsburg Seam is exposed, the dips become gentler, and the valley spreads as a wide flat, with low hills on either side. The creek flows along the synclinal trough, until within 3 miles of the Youghiogheny River, where it turns suddenly to the W., at

Strickler's mill, and traverses the first sub-axis. Almost its whole course is therefore in the Barren Measures; the Pittsburg Coal-seam nowhere descends to the water-level. Half a mile below the "Chain Bridge" it is 60 feet above the water; at Wade and Fullerton's mill, and Stouffer's mill, it is 80 feet.

High in the Barren Measures, and not more than 90 feet beneath the Pittsburg Coal, there is to be seen at the Jacob's Creek Mill (Stouffer's) a coal-bed, 2 feet thick, nearly horizontal, under micaceous sandstone; beneath the coal there is no exposure for 6 feet; then we find yellow shale, with limestone strata—in all, 10 feet thick. Two hundred and fifty yards down the creek the same limestone layers are exposed, 12 feet thick; the upper ones pure good limestone, the lower ones yellowish and shaly. These have been opened again still farther W., and on the hill to the N.W.

As the larger bands of sandstone rise successively with an E. dip, as we approach the axis they are exposed for considerable distances along the low hills bordering the creek.

At a point half a mile above Hess and Chain's are some exposures of interest; they are descending: Blue slate and sandstone, a few feet; dark olive and bluish slate, 14 feet; in the lower part of this, a band of coarse-grained nodular carbonate of iron, 4 inches thick; slate, with many nodules of ore, 15 inches; then some impure silicious ore; and under all, dark-blue and black slate, 6 feet. For an interval of 500 yards, no rocks are exposed; then we see coarse-grained sandstone, 15 feet exposed. At the mill this is 35 feet above the creek; beneath it are blue shales, 8 feet exposed, containing small nodules of good iron-ore, lying immediately under the sandstone, but not in a regular stratum.

A fourth of a mile below this, the Upper Freeport Coal-seam again makes its appearance, rising from the water with a dip of about 10° E. 20° S. It is here very irregular, as are also the accompanying rocks above and beneath it; at one place there are but a few inches of slaty coal between roof and floor; and again there are 4 feet of good coal, with little or no slate present. Sometimes a blue slate overlies the coal, sometimes the sandstone rests in immediate contact upon the seam. This rock is a coarse-grained grey sandstone very irregularly stratified, and apparently much crushed, and full of irregular concretions. The bed has here numerous openings upon its outcrop.

For a mile below the openings in the coal-bed, exposures of sandstone underneath the coal occur along the creek. About 1¼ miles below the emergence of the 4-feet (Upper Freeport) coal, the lower smaller seam has risen from the bed of the creek, and is opened at 35 feet above the water. No measurement could be made in the deserted gangway. A coarse sandstone, full of stems and leaves of plants, here rests upon the bed. At Robinson's old saw and grist mill the creek falls over a bed of massive sandstone at one place 10 feet perpendicularly; the whole exposure is 30 feet thick.

Four hundred yards below the falls are exposed, first, micaceous sandstone, 12 feet; *coal* underneath the last, 1 foot; blue shale filled with stems and leaves, 4 feet; thinly-stratified sandstone and slate, 16 feet visible. A short distance below this point, a sandstone occurs in the bed of the stream, and soon dips gently to the W.

The valley of the creek is here, at the axis, a deep-winding chasm, with lofty precipitous bluffs, in which the successive ledges of the sandstone strata of the section appear. The land above, along the line of the axis, is barren and sandy, and is known by the name of "Brush Ridge."

4.—JACOB'S CREEK IN THE SECOND SUB-BASIN.

Descending the creek from the point where the first sub-axis crosses it towards the old furnace, marked Turnbull's on the county map, the cliffs of sandstone strata are seen sinking to the water-level, and successively disappearing under it; they form while in view the prominent feature. Upon a horizontal stratum of coarse sandstone, forming the bed of the creek, above the old forge, rest 60 feet of olive-coloured slate, changing towards its upper part to sandstone. On this rests blue shale, 12 feet, from which nodular carbonate of iron was procured to feed the furnace below, but in small quantities, and of poor quality. This furnace is deserted, and its excellent stack stands as a warning, added to the many others in our State, to manufacturers of iron to study more thoroughly their ore-deposits. An immense amount of money has in this instance been lost in buildings, scarcely a trace of which remain except the stack itself.

Upon the blue shale containing the ore lies a sandstone, 12 feet thick; upon this, blue and yellow slates, 16 feet, with a thin limestone.

Upon these slates rests a coal-bed, 2 feet thick, covered by a solid sandstone rock, 9 feet thick, and resting upon a soft blue shale.

Upon the sandstone lie slates and sandstone layers, 35 feet thick. Fragments of limestone were discovered in the surface-rubbish here; then coarse grey sandstone in thick strata, 30 feet.

To the S. of the furnace in the hill-side, 70 feet above the stack, and 1 mile from the road from Connellsville to Pittsburg, the Upper Freeport Coal has been opened, on the land of Henry Sweitzer of Brownsville, and found to yield 3 feet of good coal. The distance of this Upper Freeport Coal-bed above the lower smaller seam is 170 feet. The coal does not make its appearance on the surface where it should enter the creek. Below this point to the mouth of the creek frequent exposures of the Barren Measures occur. The distance from the furnace to the mouth of the creek is 2 miles in a straight line, but is 5 miles by the windings of the stream. Near the creek's mouth the red and variegated shales of the Barren Measures show themselves, 30 feet in thickness, of soft texture, and brightly coloured. Fragments of a calcareous stratum were picked up in connection with the shale. As the Pittsburg Coal-seam is only 25 feet above the water, on the S.W. side of the Youghiogheny River, opposite the mouth of the creek, these red shales cannot be far below that bed in stratigraphical order.

5.—LOWER COALS AND BARREN MEASURES ALONG MOUNT'S CREEK.

The hills following the base of Chestnut Ridge, S. of Lobinger's Mills, and cut by Green Lick Run, are formed of the sandstone strata among the lower coals. S. of Green Lick Run a high range of land connects the ridge with the central range of the basin, cutting off the valley of Jacob's Creek from that of Mount's Creek. The latter takes its rise in a slight gap or notch in the summit of Chestnut Ridge, and almost immediately flows into and along the Barren Measures to the Youghiogheny River. A thin coal-seam is said to have been opened above Mount Vernon Furnace; it is one of the lower coals.

From peculiarities in the topographical aspect of the country E. of Mount's Creek, rather than from any observations of exposed structural appearances, it is probable that a short axis or local flexure of the rocks exists parallel with the ridge, and extending from Mount Vernon Furnace to White's Run. The outcrop of the Pittsburg Coal-seam is here separated from the base of Chestnut Ridge by a great interval, and this intervening space is occupied by high hills, in which, at least towards the top, it ought under ordinary circumstances to appear.

Natural exposures along Mount's Creek are rare; $2\frac{1}{2}$ miles above Shellenberger's mill we have this one:—Thin coal layers; blackish slate, 5 feet; coal-bed, 18 inches; grey micaceous sandstone, 8 feet; dark-blue shale, breaking up into lozenge-shaped fragments, 6 feet; light-blue and red shale, 12 feet; blue calcareous slate, full of fossils, 4 feet; blue shale, 5 feet.

The topographical sketch (Fig. 471) exhibits the remarkable retreat from and subsequent approach to the Chestnut Ridge, made by the outcrop of the Pittsburg Coal-bed *a*, under the influence of the conjectural axis. The hill *b* is capped by the *Mahoning Sandstone.* At X, at the base of the hills containing the Pittsburg Coal outcrop, are seen *the red and variegated shales* of the upper portion of the Barren Measures. At *c* and *d* are seen the outcrops of the lower coal-beds.

In the deep gap whence White Mill Creek issues, and above Breakneck Furnace at its entrance, are seen the red shales and limestone strata of the Umbral series, and not far distant an exposure of the silicious rocks of the Vespertine. At the base of the hill opposite the furnace, the fossiliferous limestone again shows itself, 4 feet thick. The Umbral ore-stratum ranges along the slope, at an elevation of 80 feet above the limestone, and over it is seen the Seral conglomerate.

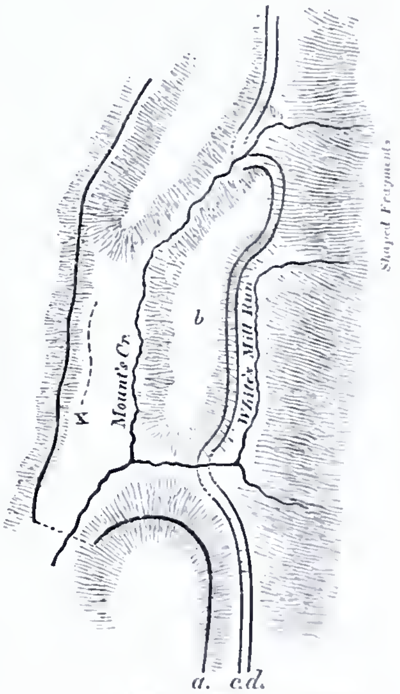


FIG. 471.—Map of Mount's Creek.

Three-fourths of a mile down the Stream and 25 feet above water-level, a coal-bed, 2 feet thick, is mined: the coal is pure; the floor is white sandstone and yellow shale; roof, 2 feet of black slate and coal intermixed. Over this, 3 feet of grey slate; over this, coarse sandstone, 12 feet. The hill above, of no great height, seems formed chiefly of sandstone.

Below White's Mill, Yellow Spring Run descends from the ridge; on this run a coal-bed, 3 feet thick, is said to have been opened.

Six hundred yards above the bridge on the Connellsville Road are exposures of sandstone and a thin coal-seam 4 inches thick. Four hundred yards below this a limestone stratum, 2 feet thick, weathering yellow, occurs; upon this rest 6 feet of shale, and yellow micaceous sandstone; on this shale, 10 feet. Below the bridge, and extending to the mouth of the run, are exposures of a sandstone, 40 feet thick. All these rocks are in the upper part of the Barren Measures.

The few small runs that flow from the ridge into Mount's Creek, through gaps in the range of sandstone hills at its base between White Mill Run and the Youghiogheny, seldom expose the lower Coal-measures.

Along the Youghiogheny, where it cuts the ridge in a deep wide gap, numerous exposures occur, from which the section (Fig. 472) was compiled, some parts of it being measured, others estimated. The site of Connellsville is on the 65-feet sandstone of the section, a short distance beneath the Pittsburg Seam. The high knob opposite the town, and S. of the river, is of the same rock.

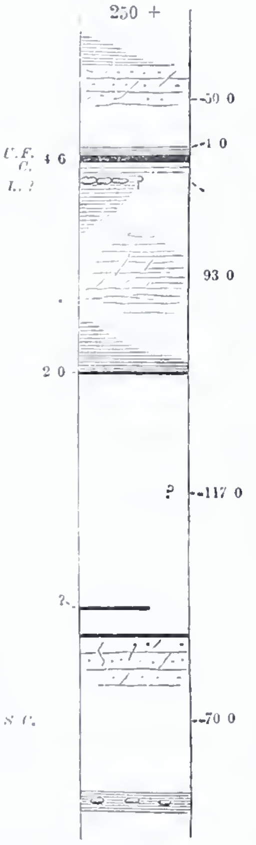


FIG. 472.—Youghiogheny Section.

Commencing our description of the section with its lowest rock, the Seral conglomerate, we find all the series up to the Pittsburg Coal dipping W., and disappearing beneath the bed of the river below Connellsville in a distance of about 2¼ miles. In the gap the rocks dip from 15° to 20°, but the dips become always gentler, until above Connellsvillle they are quite horizontal—a phenomenon repeated in every gap in Chestnut Ridge, so that, the distance of any rock from the axis being known, its inclination may be approximately calculated.

The Seral conglomerate forms the bed of the river at Rotrock's Eddy, 2¼ miles above Connellsville, and is from 60 to 70 feet in thickness. It is here a dark-grey coarse-grained massive sandstone, not a conglomerate in any part. Immediately beneath it is the Vespertine ore, hereafter to be spoken of: the sandstone ascends bold ledges nearly to the summit of the ridge.

The two coal-beds of the section are opened in the end of a high spur, the body of which is formed of the Mahoning Sandstone, and part of the shales of space 250 + of the section. The Mahoning Sandstone is probably 50 feet thick. The 2-feet coal-bed is a rich soft crumbling coal, containing very little slate, and has not been much wrought.

The larger upper (Upper Freeport Coal) bed has been opened at several points: it is at one point 3 feet thick, with a roof of yellow shale, 4 feet thick, and full of vegetable remains: on this rests a sandstone. At another place it measures over 4 feet, with roof of dark-blue slate, above which is the sandstone. The coal is good, and harder than that below, and richly bituminous.

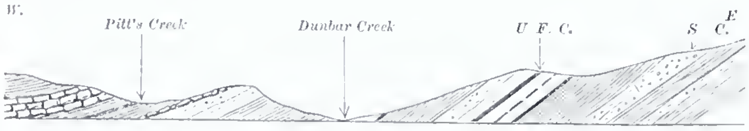


FIG. 473.

Fragments of the Freeport Limestone were found in the interval, but no rock *in situ*.

The valley of Dunbar Creek makes the middle of the section difficult to compile with accuracy. The longitudinal section will exhibit the relation of the beds to the face of the country.

The red and variegated shales are seen at the base of the hill, of which the limestone under the Pittsburg Coal forms the coping. They are about two-thirds of the way up in the series of the Barren Measures.

The third coal-seam is 1 foot thick at its exposure on the river, but to the N. of this exposure it is seen to measure 2 feet.

The Pittsburg Seam, after disappearing beneath the river a short distance below Connellsville, emerges again at a point 2 miles below the town, near the Broad ford ; and thence to the first sub-axis the river repeats the Connellsville Section in its exposures. But in the centre of the synclinal trough there is a longitudinal roll, which causes the Great Coal-seam, after having attained an elevation of 30 feet, to descend again nearly to the water, and then reascend towards the sub-axis. The presence of this roll adds probability to the suggestion that a similar one traverses the Upper Mount's Creek district, as described in page 609. For some distance the river has its course along the axis of this roll, the rocks appearing quite horizontal.

The limestone strata beneath the Pittsburg Coal are exposed at Lobinger's salt-well, 2 miles below Broadford. Here the Pittsburg Coal is 4 feet above the water-level.

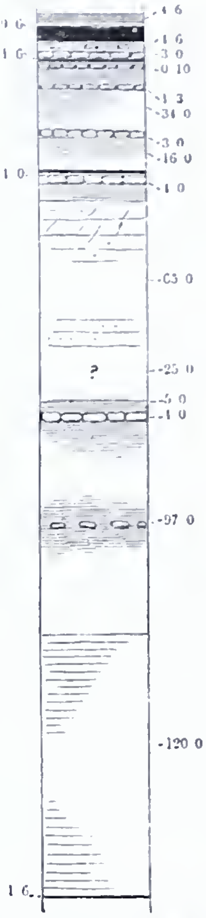


Fig. 474.—Youghiogheny Section, lower part of Connellsville.

One mile below the salt-well the rocks below the Pittsburg Seam are exposed ; the section is continued downwards by following the exposures of the river as it enters the arch of the sub-axis, near the town of Liberty ; and if placed in comparison with the upper portion of the Connellsville Section, exhibits the striking and endless diversity consistent with the widest and most positive general conformity. This section, expressed in words, is as follows :—

Pittsburg Coal, 9 feet ; Yellow Slate and blue shale, 16 feet. Limestone, 10 feet. Yellow Shale, 5 feet ; Interval, 20 feet ; Coarse Grey Sandstone, irregularly stratified, 25 feet ; Interval, 15 feet. Olive Shale, 20 feet ; Micaceous Sandstone, 9 feet ; Yellow Slate, 15 feet.

Three-fourths of a mile below East Liberty, and a short distance from the river, on the land of Mr Strickler, there is a coal-seam, 15 inches thick : upon this, blue shale, 4 feet ; fossiliferous limestone, 6 inches ; blue shale, 7 feet. Under the coal, blue slate, 4 feet. These rocks occur, as nearly as can be estimated, 35 or 40 feet beneath the former. The coal-seam again appears 400 yards farther down the river, 35 feet above water-level. Under it, along the river, is a continuous stratum of coarse grey sandstone, fully 70 feet in thickness : under this, yellow shale, 25 feet ; sandstone, 30 feet ; shale, 25 feet. At the old furnace, known as the Franklin Ironworks, and near the old forge and below it, a sandstone stratum, fully 40 feet thick, comes next in order : it is thinly laminated, grey, and micaceous, with dark olive shales ; it has a very gentle East dip. Here fragments of coal are found in the soil, but the seam is not visible.

One and a half miles below this upon the river are horizontal strata of coarse grey sandstone ; 30 feet of this are seen exposed half a mile below, and other similar exposures as far as " the rapids," where the river has a very considerable descent over the lower sandstones of the Barren series (Mahoning Sandstone, &c.)

Four hundred yards above the mouth of Washington's Run, the " 4-feet " (Upper Freeport) Saltzburg Coal-bed is opened, measuring from 4½ to 5 feet of good coal, divided as usual by a thin slate-seam near the middle. Blue slate is the roof, and over this the Mahoning Sandstone.

At the mouth of Washington Run, exposures give :—

Sandstone, coarse, massive, 80 feet ; Olive Slate, 4½ feet ; *Coal,* 15 inches ; Shale, containing calcareous and ferriferous nodules, 4½ feet ; Olive Slate, 4 feet ; Micaceous Sandstone, 4 feet ; Olive Slate, 4 feet ; Micaceous Sandstone, 5 feet ; Blank at the mouth of Washington Run, perhaps 65 feet ; Blue Shale, 4 feet ; *Coal,* 4½ to 5 feet.

If the lower bed be the Upper Freeport Coal, as we suppose, the upper one is the Elk-Lick Coal ; or the upper one may be equivalent to the third coal-bed in the Connellsville Section across the sub-basin.

All these rocks disappear beneath the bed of the stream approaching Perryopolis, a village situated on a high hill of the Barren Measures. Nearly 2 miles below the mouth of Washington Run the following section of their upper rocks is exposed :—

Yellow Shales, 15 feet ; Solid stratum of Sandstone, 16 feet ; Sandstone, 6 feet ; Yellow Slate, 10 feet ; Red Shale, 12 feet ; and Sandstone, 24 feet ; Yellow, blue, and variegated Shales, about 45 feet above the water.

Above these rocks, at a point on the river a fourth of a mile below, is a coal-seam, 18 inches thick, a short vertical distance beneath the Pittsburg Coal. This locality is three-fourths of a mile above the Shovel-Factory.

Two miles below Perryopolis the river turns to the N., and its valley coincides with the strike of the rocks for about 2½ miles. At the Shovel Factory the Pittsburg Seam is 15 feet above low-water level. Up the river it rises rapidly towards the first sub-axis; down the river, it rises slowly; and one mile above the mouth of Jacob's Creek, is 70 feet above the water: thence descending, it is seen 35 feet above the water at the mouth of Jacob's Creek. A wide roll in the rocks crosses the river at this place, therefore, but we saw no evidence of its existence N. or S.

6.—LOWER ROCKS SOUTHWARD OF THE YOUGHIOGHENY.

Dunbar Creek rises in the valley E. of Chestnut Ridge, through a deep notch in which it flows, and empties into the Youghiogheny opposite Connellsville. It traverses the Barren Measures for 2 miles above its mouth, the sandstone above described often forming from the water's edge a perpendicular wall or bluff, the surface of which is rough, with rounded cavities. Higher up towards the bend of the creek, the Pittsburg Seam, which at the river outcrops at the base of the ridge next W., sweeps round and appears at the summit of the hill above the sandstone.

Here the creek issues from the ravine in the ridge, and affords exposures of the lower series of rocks. Under the 65-feet sandstone of the section (Fig. 472) occur 16 feet of dark olive and brown shale, and in the middle of these a coal-bed from 6 to 10 inches thick, with calcareous nodules below the coal.

Two hundred yards above this, along the run at Dunbar Mill, the following section is exposed:—

Coarse grey Sandstone, confusedly mixed with yellow shale, 25 feet thick; Yellow and dark olive Slate; Blackish Slate, 45 feet; Yellow Slate, 8 feet, micaceous, flaggy. Thick coarse sandstone, 50 feet; Olive-yellow dark Slates, 6 feet. *Coal opened here* 4½ to 5 feet; at another opening it is thinner; floor, blue shale. Shales (coal not discovered) 100 feet. Seral conglomerate, 100 feet. *Coal*, 6 inches; Olive and dark-blue shales with iron ore; then limestone and sandstone strata.

The Seral conglomerate rises from the creek about a mile above Dunbar Mill, at the Old Union Furnace, as a coarse-grained, contorted, and irregularly-stratified sandstone, cropping out above the furnace 80 feet high.

S. of Dunbar Creek, the 65-feet sandstone again forms a ridge separating the range of hills containing the outcrop of the Pittsburg Coal from Chestnut Ridge. Gist's Run gives but few exposures of rock in place, and flows in the Barren Measures. For the last mile and a half of its course, having cut through the separating ridge, it courses by the foot of the slope, along which ranges the outcrop of the Pittsburg Seam. The topography changes gradually S., until, at a point opposite Mr Braddock's, the outcrop of the Pittsburg Seam is on a gentle summit, from which, going E., one crosses a broad flat, and rises very gently upon Chestnut Ridge. This flat continues but a short distance S. of Mr Braddock's, and gives place to the high land at the head-waters of Cover Run, which is a branch of Redstone Creek. There, on the farm of Mr Pennick, the Pittsburg Seam is opened. High on the side of the ridge a bed of coal, 4 feet thick, is said to have been entered, and a smaller bed at a spot to the N.E.

Proceeding S. as we approach the gorge of Shute's Run, the denudation is more considerable, the valleys deeper, and the hills sharper. Shute's Run cuts down into the Vespertine sandstones. Opposite and above the furnace the silicious and calcareous layers of the Umbral series are exposed, with the red shales of that formation, and the ore hereafter to be described. The ends of two hills, cut off from the main ridge by two small runs, present the strata of the Seral conglomerate, which are here of no great thickness, and also the sandstones related to the lower coal-beds.

The upper coal-bed (Upper Freeport Coal ?) is here 3½ or 4½ feet in thickness, and of good quality. The (Mahoning ?) Sandstone is seen above it. The other bed is said to have been also opened at one time. An occasional small exposure of shale or sandstone is all that can be observed above, in the Barren Measures.

A reliable section along Redstone Creek could not be compiled from exposures upon the first sub-axis, because of their unfrequency, the serpentine course of the stream, and the obliquity of its traverse N.W. through the sub-axis.

The length of the course of the stream from the outcrop of the Pittsburg Seam, at water-level, on the one side, to its outcrop at water-level on the other, is between 8 and 9 miles, while a line across the axis would not exceed 4 miles. The lowest rock brought up by the axis, as would appear by a section, is about 30 feet below the lower coal. This middle point of the subordinate axis is one mile and three-fourths below the place called Middletown. The lower coal-bed sinks E. below water-level a short distance above Work's mill; and W. down the creek on Mr Hill's land, where 2½ or 3 feet of rich black solid coal is mined from the bed of the stream. Its appearance is that peculiar to the class of coals called Splint Coals: it is very hard, and exhibits no tendency to columnar structure, but comes out in long flat slabs, which break with rhomboidal fracture. Slabs 7 feet long, and not more than 8 or 10 inches thick, and 18 inches wide, have been taken out of the bed of the creek. The usual character of the other thin coals (whether mined in flowing water or in a dry hill-side) is that of a soft crumbly mass, falling readily into a multitude of small prisms ranged in vertical columns across the bed.

The upper coal-bed (Upper Freeport Coal) is exposed near the sub-axis, in a hollow to the N. of Work's mill, and is there from 18 inches to 3 feet in thickness: it is covered by slates and shales, no sandstone being visible. This is the most Western exposure of this bed on the E. side of the first subordinate axis: it descends Eastwardly, and disappears beneath water-level at Bryer's mill, near the bridge, a short distance above Middletown. It is repeatedly opened opposite the village, where it is 3 feet thick.

The small seam above the last mentioned has been opened near Mr Gadden's residence, and is said to have exhibited 2½ feet of impure slaty coal, full of sulphuret of iron.

The sandstone stratum between these two coal-beds, about 40 feet in thickness, is exposed upon the creek, and extensively quarried for the grey micaceous slabs which its beautifully regular stratification affords.

The dips on both sides of the small axis are very gentle, and the lower coal group disappears W. beneath the creek near Sharpless's mill, a few hundred yards below which the Pittsburg Seam enters the water. Not even the upper members of the Barren group are again visible until we approach the mouth of the Redstone, where a few of the strata immediately below the Pittsburg Coal-bed are brought up again by the Brownsville axis.

Let us resume the tracing of the E. outcrop. S. of the flat of Shute's Run, the hills containing the Pittsburg Coal-seam become high, approach the ridge closely, and almost abut upon its base; but they recede from it again, and diminish in height as they enclose another characteristic flat, watered by the upper tributaries of the Redstone. At Munroe the Pittsburg Seam is at the water-level, and low hills rise over its outcrop; it is not seen again until it reappears in the hills to the S. of the creek. All the rocks above and below it have been so eroded that diluvium completely conceals them from view.

The lower group occupying its usual place, the large sandstones (Mahoning Sandstone, &c.) form benches upon the flank of the ridge. Where the National Road crosses it, one of the head-branches of the Redstone cuts down to the red shales and limestone of the Umbral series, and exposes them to view; but none of the numerous excavations for the road have exposed even the black soil of any of the lower coal-seams or the Umbral ore-bands, although the calcareous and silicious strata appear in them. Unsuccessful but very careful search was made for a small coal outcrop, said to have been seen at the run in the gap. Neither does the other head-stream of the Redstone (next S. of the one mentioned) give exposures of these coal-beds, nor does it penetrate the strata to as great a depth as the other. Between these two streams the lower sandstones stand out in a high knob (apparently separate from the ridge), which is quite a conspicuous object as seen from Uniontown, and from points at a great distance to the W. and N. of it. This has led to an error in the maps of the county, where this knob is represented as a distinct mountain, while it is in fact only one of a range of hills along the side of the mountain, and it is constructed like the rest, being an isolated segment of the lower sandstones in outcrop; but is somewhat superior in height, and has deeper traces of denudation around it. A similar instance occurs farther S.

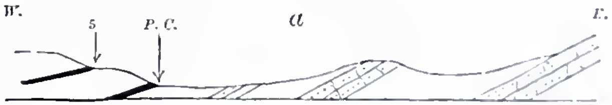


FIG. 475.

At Munroe, *a* (Fig. 476) represents a section of the ridges from the Pittsburg Coal-bed to Chestnut Ridge. One and a half miles farther S. the Pittsburg Coal-seam crosses the wide flat of Lick Run and Redstone Creek. Between the head-waters of Lick Run and George's Creek the sandstone strata of the Barren Measures are seen forming a sub-ridge, elsewhere swept away.

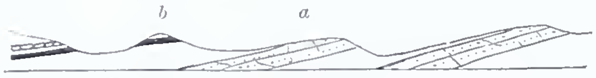


FIG. 476.—Section from Chestnut Ridge to the Pittsburg Coal-seam.

S. of the last locality a wide valley begins and continues to a point 2 miles beyond Oliphant's furnace, and extending from the base of the Chestnut Ridge to a range of gentle acclivities, in which the Pittsburg Coal-seam has its outcrop. The latter, however, sometimes runs its line of outcrop in the flat or terrace, but sometimes also high upon the slope. The valley widens S. towards the furnace, and when within a mile of it presents an aspect as at *b*, a knoll rising upon its surface, containing a fragment of the bed. At the furnace the outcrop is half a mile distant from the base of Chestnut Ridge, the furnace itself standing at the outcrop of the great sandstones at its base. Two miles S. of the furnace the flat terminates against a sloping spur of Chestnut Ridge connecting it with the acclivities on the W.

George's Creek.—Outcrops of the lower coal-seams have nowhere been discovered in the transverse sections of the sandstone range of hills or terraces upon the flank of Chestnut Ridge along this valley.

Haydontown is situated at the mouth of a gorge, by which one of the forks of George's Creek issues from Chestnut Ridge. Near it one of the lower seams is opened, but which one we could not ascertain.

The S. fork of George's Creek flows through an extensive flat extending to the forks at Woodbridge, below which the valley of the creek is but a narrow pass between the hills containing the Pittsburg Coal-bed. The woodcuts (Figs. 477 and 478) are intended to show the shape of the basin at George's Creek and at the Virginia State line respectively. The creek exhibits numerous exposures of the Barren Measures in its course to the river.

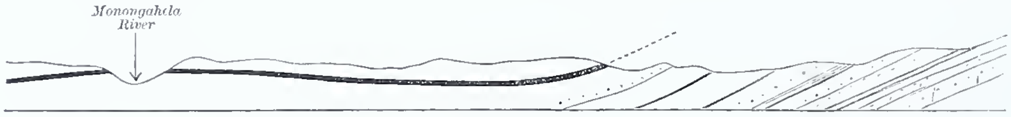


FIG. 477.

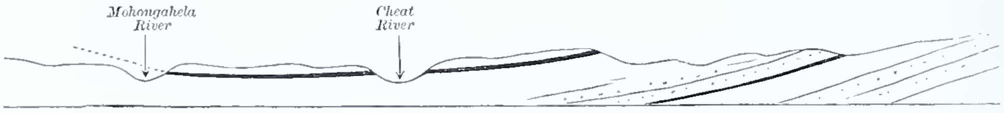


FIG. 478.

At Long's mill, 2½ miles from the ridge, the Pittsburg Coal is 173 feet above water-level; and beneath it, 45 feet above water-level, is seen the outcrop of a small coal-seam. At the water's edge occur yellow slates, 6 feet thick, containing a 4-inch band of coarse-grained nodules of carbonate of iron; upon these rest thin layers of micaceous sandstone, 12 feet thick; yellow slate, 6 feet exposed. Coal, 2 feet, mentioned above; roof, olive slate, 12 feet; strata horizontal.

Farther down the creek, by the Morgantown Road, sandstone is seen, 30 feet of it being exposed, and underneath it a limestone stratum 5 feet thick, upon yellow slate 25 feet. These continue to exhibit cliffs down the creek, as at Crow's mill. Above Geneva, the rock begins almost imperceptibly to dip W. Half a mile above Geneva, the little coal-seam is 125 feet below the Pittsburg Seam, and disappears beneath the creek. At Geneva, the sandstone stratum beneath the Pittsburg Seam, which skirts the summits of the hills, forms high cliffs along their sides.

To the S. of the head-waters of George's Creek there runs a small valley of denudation, along the base of Chestnut Ridge; for a space of 2½ miles it is terminated at the Virginia State line by a transverse spur of the ridge. This is watered by Rubble's (M^cCulloch's) Run. On its W. side runs a high range of hills, still beyond which is the range in which the outcrop of the Pittsburg Coal-bed occurs, the two being separated by the valley of Grassy Run.

The accompanying sketch will explain the features of the country better than a description in the text—

a being the flat of George's Creek, *m n* the Grassy Run and M^cCulloch's Run, V. L. the State Line, *a a* the outcrop of the Pittsburg Seam with its openings, and *Fur.* the furnace.

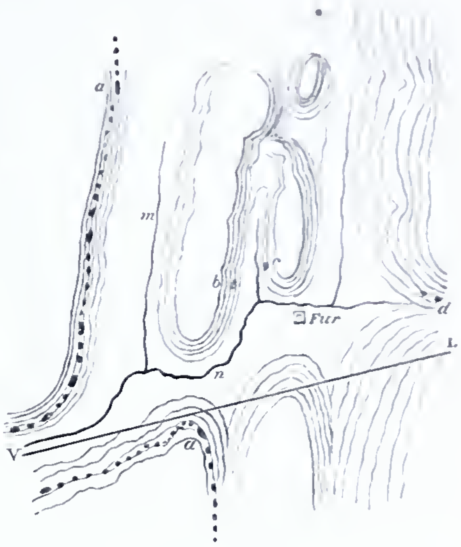


FIG. 479.

At *b* a small coal-seam is opened, and the ridge above it is composed of Barren Measures. At *c* the Elk-Lick Coal-bed, 4 feet thick, is opened, and the ridge above it, composed of 40 feet sandstone, underneath the coal-bed. It is separated from Chestnut Ridge by a deep and narrow ravine; though, viewed from the W., no such separation is visible, but it appears from thence to form part of its flank. At *d*, the Upper Freeport Coals, and those below it, are opened. Here there is a deep cut in the side of the ridge, developing the Umbral red shales and rocks above.

The Upper Freeport Coal (here, as elsewhere, a double bed 4 feet thick) is exposed in the ravine about 400 yards above the furnace-dam. Ore has been obtained under the coal, and a thin limestone is its associate rock.

The Elk-Lick Coal, also 4 feet thick, is opened below Mr Duncan's residence, and yields good coal. The second thin coal-seam, seen above the Elk-Lick Coal, crops out near Rubble's mill, down the run which flows from thence through the Barren Measures to its mouth, while the Pittsburg Coal everywhere occurs near the summits of the hills on either side, and in a similar position along Cheat River. Here the rocks gradually rise W., until, at the mouth of the river, the Pittsburg Coal-bed is 371 feet above water-level. The lower coal-beds are nowhere exposed along the river.

Before passing to the detailed description of the Pittsburg and upper coal-beds, a few words must be said about the general structure of the surface, from one large creek to another, along the sub-axes. The preceding description has been almost wholly confined to the sections developed in the deep thorough-cuts made by those streams. We begin with the first sub-axis at the Conemaugh.

A series of high irregular hills, composed of the Barren Measures, marks the course of the first sub-axis to the Loyalhanna. In the hollows between these hills occur frequent exposures of the upper portions of this group, but the lower coal-beds are never seen. Between the Loyalhanna and Sewickly Creek the axis is still more plainly traceable by a similar series of hills, especially if seen from Chestnut Ridge. Among the hills the red and variegated shales of the Barren Measures are commonly traceable with some of the massive sandstone strata along the runs. The thin coal-beds in that series frequently exhibit the black lines of their outcrop; but none of the ravines, except those close to the two main streams, sink to the lower coals. On some of the highest summits a sandstone is observable, which there is reason to believe is identical with the first massive stratum beneath the Pittsburg Coal-bed; also in the deepest ravines there is one, which is probably the Mahoning Sandstone, above the Upper Freeport Coal.

The hills of the axis on either side of the Sewickly (where its course is along the axis) are very high, especially those on the E. side. Near New Staunton one of the thin Barren Measure coal-beds has been opened with a thickness of 18 inches; it is full of sulphuret of iron.

From this point to Jacob's Creek the axis is not so apparent along the surface, but is still distinguishable when its hills are compared with those of the troughs on each side. Here the red shales are quite thick; they frequently occur on the hill-sides, and display here and there the unopened outcrops of the thin coal-seams.

Jacob's Creek cuts down nearly to the Seral conglomerate. S. of it the line of axis traverses very high ground, called Brush Ridge, which is sandy and barren, from the disintegration of the Mahoning Sandstone, which forms the arching rock. Here the first sub-axis seems to be at its widest.

From the Youghiogheny to the Redstone the axis is not very plainly marked on the surface. Very high knobs denote it on the Youghiogheny River. The Mahoning Sandstone appears in the deepest ravines; the Upper Barren Measures form the rest of the surface. Approaching the Redstone, the land declines in altitude as the axis is sinking and spreading out. S. of Redstone Creek the axis continues gradually to sink; the outcrops of the Pittsburg Coal-bed on each side of it approach each other, and meet at a point 2 miles S. of the National

Road, beyond which that coal-bed arches over the now almost vanished axis. At Redstone Creek there are many deep lateral depressions which cut down to the Mahoning Sandstone, but the lower coals nowhere come up much to the S. of the valley of this creek. The axis is barely determinable where it crosses the Monongahela River below the mouth of Cheat River.

The second subordinate axis causes the valleys of the Loyalhanna, Beaver Dam Run, Brush Creek, and Little Sewickly, to present exposures of the Barren Measures, but not of the lower coal-beds, except the Loyalhanna, which, as we have seen, displays them also. Here and there the smut along the crops of the thin coal-seams of the Barren Measures is seen on the sides of the hills, which, when beheld from one of the knobs along the line of the first sub-axis, mark the line of the second sub-axis. From certain points this range looks like a regular but very low ridge, broken at intervals by gentle depressions. It does not seem to have suffered so much from denuding agencies as the first sub-axis, except towards its termination, where it has been deeply trenched. A barren soil marks its whole course, the hills being composed of the sandstones and silicious shales of the Barren Measures ; but along each side runs a strip of excellent land, the soil of which owes its fertility to the outcrop of the upper shales and limestone strata under the Pittsburg Coal-bed. These alternating belts are strikingly contrasted. The Greensburg and Pittsburg Turnpike crosses the second sub-axis near Grapeville.

CHAPTER XXV.

1.—PITTSBURG COAL-BED, AND THE ROCKS ABOVE IT, IN THE THIRD BASIN S. OF THE CONEMAUGH.

THE upper group of Coal-measures, with the Pittsburg Coal-bed for its base, occupies the central region of the first subdivision of the Third Basin, between Chestnut Ridge and the first anticlinal sub-axis to the W. of it, from the Conemaugh River to the Virginia line, sometimes occupying a very narrow strip of surface, of small thickness, and again, where it is of greater thickness, spreading over a wider belt. In describing it, the Eastern and Western outcrops will be traced from stream to stream.

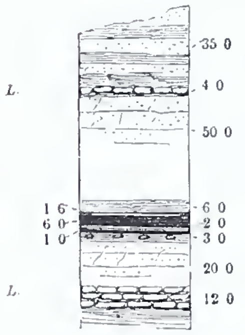


FIG. 480.

Upon the Conemaugh (as will be seen by a reference to Fig. 480), at and opposite to Blairsville, there are very few rocks above the Pittsburg Coal-bed preserved in this basin. A Section here includes the following strata :—

Yellow and olive Slates, with sandstone, 35 feet ; Limestone, 4 feet ; Coarse Sandstone, irregularly stratified, 50 feet ; Black Shale, 6 feet, with *Coal*, 1 foot ; *Coal*, 6½ feet ; Black Slate, 2 feet ; *Coal*, 1 foot ; Dark-blue Shale, with iron nodules, 3 feet ; Micaceous Sandstone, grey thin strata, 20 feet ; Limestone, with shaly layers, 12 feet, &c.

The Pittsburg Coal is finely exposed with its superposed sandstone at the mouth of McGee's Run, 6 feet in thickness : beneath it yellow slate and sandstone, 10 feet ; then limestone with interposed layers of blue slate, 8 feet ; then yellow and blue slate, 15 feet.—(See Fig. 481).

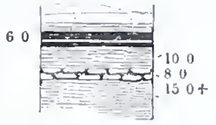


FIG. 481.

At one exposure the coal is divided (as in Fig. 482) thus :—

Coal ; black Slate, 1 foot ; *Coal*, 18 inches ; Shale, containing nodules of carbonate of iron and carbonate of lime, 18 inches ; Yellow Slate.

The scattered nodules have become a solid bed of limestone 2 feet in thickness, and separated from the floor of the coal-bed by a few feet of slate. Beneath the coal are—

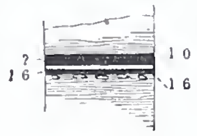


FIG. 482.

Black Slate, 1 foot ; Nodules of iron and limestone, 18 inches ; Blue Shale, 6 inches ; Nodules of Limestone, 1 foot ; Blue Shale, 18 inches ; Blue Slate, 3 feet.

At Wallace's Mill, a short distance S.W. of the mouth of the Run, the coal is 6 feet thick, but over it rest shale and sandstone, 20 feet ; then limestone in two beds 5 feet thick.

The sandstone at the river has here been subjected to one of its local changes (Fig. 483). At the mill, 1 mile S. of Wallace's mill, the coal, 6 feet thick, rests upon sandstone, while the rough brownish-grey Pittsburg Sandstone is seen in the hill above. The dip is here to the N.W., at a sensible angle.

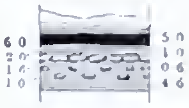


FIG. 484. -Pittsburg Coal-Seam.

From this point to Derry there are few exposures of the coal-bed. Half a mile to the E. of Derry, it is opened, and is 7 feet thick; it is also frequently opened between this point and the Loyalhanna. At Mr Shall's bank it is 8 feet thick, having much shale and slate-rock, containing a few silicious layers over it. It dips under water-level on the Loyalhanna Creek above Baldridge's mill.

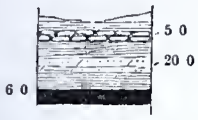


FIG. 483.—Pittsburg Coal-Seam.

Upon its Western outcrop, between the Conemaugh and Loyalhanna, the Pittsburg Coal has numerous openings. They follow its gradual rise along the river Westward. Opposite Blairsville it is 115 feet above the water-line. Above the coal are yellow and bluish shale 12 feet, coarse grey massive sandstone, irregularly stratified, and weathering with roundish holes, 30 feet; limestone, yellowish, impure, 4 feet; and yellow and olive shales, 35 feet. The hill rises to a considerable height above, but presents no farther exposures.—(See Fig. 486.)

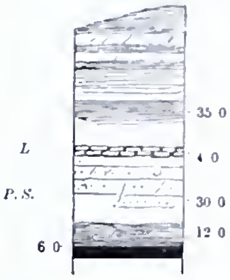


FIG. 486.—Conemaugh.

The distance between its Eastern and Western outcrops increases Southward, the basin deepening, and permitting a second superior limestone to come in, as seen in Fig. 485.

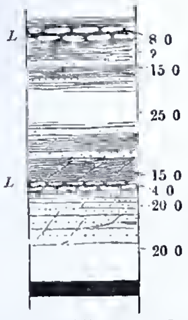


FIG. 485.—Loyalhanna River.

At New Derry, 6 miles S. of Loyalhanna and Blairsville, the distance across the area of the bed is 1½ miles.

There are a number of openings 4 miles W. of New Derry, under an elevation, called the Barrens, formed of the Pittsburg Sandstone above the coal. The bed is 7½ feet thick, a thin seam of slate separating the lower 2 feet of coal as an under bench (Fig. 487); the roof is of black slate containing thin layers of coal. The dip is gently Eastward, but the bed, as exposed along the Little Run, exhibits several wrinkles or gentle undulations.

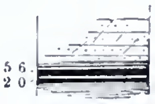


FIG. 487.

South-westward to the Loyalhanna, openings are numerous; the bed, after reaching the Creek, descends slowly in an Eastwardly course to the water, under which it dips at Chambers's mill, about 300 yards W. of the centre line of the trough. Here is seen, beneath the coal, slate 8 feet thick; resting upon limestone, 6 feet (see Fig. 488). The Pittsburg Coal itself is about 8½ feet thick, the Pittsburg Sandstone above it forms the banks of the creek, back of which, to the N. and S., along the centre of the trough, there stretches a beautifully level country, presenting no rock-exposures higher in the series. About a fourth of a mile below Baldridge's mill, however, we have exposures (Fig. 486) as follows:—

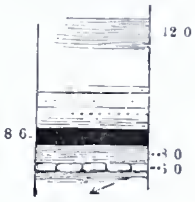


FIG. 488.

Limestone, in thick layers, 8 feet, exposed at the summit of the hill, about 100 feet above the Pittsburg Coal; Interval; Olive and yellow Slate, with sandstone strata, 15 feet; Yellow silicious Slates, 25 feet; Dark-blue Slate, upper part silicious, 15 feet; Yellow Slate, with limestone in alternating layers, 4 feet; Coarse-grey Sandstone, with occasional layers of slate between it and the coal, 20 feet out of 40 exposed. *Pittsburg Coal*, 8 feet. Beneath it, 80 feet, with no exposures.

Along the middle of the trough the hills are generally composed of the sandstones and shales above the first limestone-band, and in these are occasionally seen the smuts of one or two small coal-beds, nowhere opened. These coal-beds are doubtless the equivalents of the first two thin coal-beds of this upper group, viz. the Redstone and Sewickly seams.

2.—PITTSBURG COAL S. OF THE LOYALHANNA—FIRST SUB-BASIN.

This bed appears at Baldridge, in the bank, 500 yards above the mill, upon a stream which flows into the Loyalhanna. The coal, as opened, is between 7 and 8 feet in thickness; sandstone in some places rests immediately upon the coal, at others it is parted from it by 5 or 6 feet of slate. The coal-bed ranges through the adjoining hill, and issues upon its Eastern face on the Greensburg Turnpike, where it is 8 feet thick. There are many openings upon the Eastern outcrop besides this one.

Half a mile from Youngstown, 20 feet of blue and blackish slate rest upon the coal, while but a short distance off, at the creek, coarse sandstone occupies the same interval.—(See Fig. 491.)

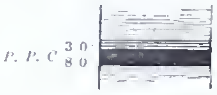


FIG. 489.—Pittsburg Coal, Nichol's Bank.

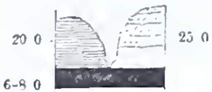


FIG. 490.

Two and a half miles S.W. of Youngstown, a range of hills, too low to receive the Pittsburg Coal at their summits, lie between the Chestnut Ridge and the high lands in the centre of the trough, at the very base of which the Pittsburg Coal shows its outcrop. This is the case at Mr Nichol's bank, where the seam measures 8 feet, with a stratum of alternating coal and slate 3 feet more above it, as in Fig. 489. This is perhaps a mile Eastward of Pleasant Unity. Openings are numerous from thence to the Big Sewickly Creek, along both sides of the valley of which the seam is frequently exposed and mined. At Fisher's mill, upon the Sewickly Creek, the second limestone above the Pittsburg Coal, at water-level, and nearly horizontal, is composed of four strata ; the uppermost is 3 feet thick, the next 16 inches, next 12 inches, lowest 2 feet. Eighteen inches of slate separate these from two more, each 6 inches thick. Some of these layers are of a bright ochre yellow, others a pure blue.

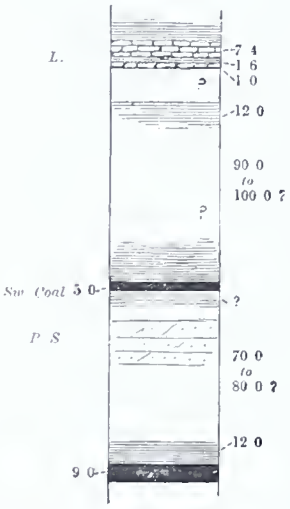


FIG. 491.—Sewickly Creek.

A mile below the mill, a coal-bed 5 feet thick appears (Fig. 491), which is doubtless the Sewickly Bed, covered by dark-blue and brownish slates, 20 feet ; below it are hard bluish-grey slates. The coal is solid and pure, richly bituminous, and free from slate. The height at which it stands above the Pittsburg Coal is rather doubtful. At first it was estimated at 45 or 50 feet, but, allowance being made for dip, it may be nearer 80 feet. In this interval we find micaceous sandstone 12 feet exposed ; the latter resting upon the Pittsburg Coal, here 9 feet thick, and occupying, where first seen, the bottom of the creek.

Upon the Western outcrop, the Pittsburg Coal rises along the Southern side of the Loyalhanna Valley, from Chambers's mill, with a dip of 10° to 13°. It is cut at Beatty's Station of the Pennsylvania Railroad, and is frequently drifted in upon at points between the creek and the Greensburg Turnpike. It always yields about 8 feet of coal, and has usually, as its roof, a stratum half slate, half coal, and from 2 to 3 feet in thickness. It crosses the turnpike near the sixth milestone. Over it here is a mass of brownish shale in place of the coarse-grained Pittsburg Sandstone.

At the coal-banks S. of the Turnpike it is 8 feet thick, and bears its upper slaty member, but dips more steeply than usual. Southward it is opened at several banks, and at last in a deep ravine, cutting down to the Sewickly. It passes this ravine, however, Westward, and is mined on the hill overlooking the first sub-axis.

The two ranges of outcrop are, in this section of the trough, distant from each other from 1¾ miles in the deepest ravines to 2¼ in the highest land.

Upon the Loyalhanna we have 107 feet of rocks above the Pittsburg Coal. The highest rock in this district is a limestone, capping a hill about one-fourth of a mile below Baldridge's mill. Higher rocks lie unexposed in the more central summits of the trough ; these are principally olive and yellow slates and sandstones. The side-hills N. of the turnpike do not rise to any great height, being usually capped by the limestone when the Pittsburg Coal is mined in the bottom of the ravines. The hills more in the centre exhibit the limestone in their ravines, and are themselves built up of superior rocks.

These central hills Southward of the turnpike become very lofty, and near their summits is seen the outcrop of another coal-bed, which may be the Uniontown Coal. The hills decline again as we approach the valley of the Sewickly Creek, and contain two outcrops of apparently thin seams above the first limestone-bed, and one between it and the Pittsburg Seam. The limestone descends both ways to the level of the water of the Sewickly Creek, and is estimated to be 170 feet above the Pittsburg Coal.—(See Fig. 491).

3.—THE PITTSBURG COAL-BED SOUTHWARD OF THE SEWICKLY.

The E. outcrop of the Pittsburg Coal, after passing the Sewickly, approaches closely to Chestnut Ridge, and ranges along the first line of hills facing the ridge. Openings upon it are numerous. At Lemon's bank the bed measures 8½ feet, upon which is 1 foot of black slate, and upon this again coal, with thin layers of slate, 3 feet thick; this is covered by 1 foot of slate, and then the Pittsburg Sandstone (see Fig. 492). At Mr Moyer's bank, 1 mile S.W. of the last, 8 feet of coal are covered by coal and slate interlayers 4 feet in thickness.

FIG. 492.—Lemon's Coal.

Towards Jacob's Creek it is frequently mined, as at Hooker's and Lobinger's banks (the latter on the turnpike), where the coal and slate top-bench are also 4 feet thick. This general feature varies in different localities only in the proportions maintained to each other by the coal and slate. At Jacob's Creek the Pittsburg Coal descends along the stream with a dip of 8° or 10°, and is opened on Mr Sharp's farm (where 5 feet of slate and coal form the upper member), and at Moyer's bank, 300 yards below Meshoyer's mill, 20 feet above water-level. Here it is 10 feet thick, with 4 feet of coal and slate above it (see Fig. 493). At Terisman's it is but 8 feet above the water, and of the usual size, and dips beneath the water below the mouth of Green Lick Run. It is opened also half a mile N. of "the Chain Bridge."

FIG. 493.—Moyer's Coal.

There are other openings upon a stream that enters Jacob's Creek at the bend below the bridge. The bed passes through the hill to the W., and is opened at Overholt's mill in the next parallel ravine, and almost upon a horizontal plane, and might be opened at the end of the hill near Jacob's Creek. It rises rapidly through the next hills W., and soon caps the hills, and outcrops towards the next sub-axis.

Upon its W. outcrop the Pittsburg Coal-bed was opened one-fourth of a mile below its first reappearance upon Sewickly Creek, with a dip of 2°—it was 8½ feet thick; roof bluish slate, with thin coal-layers, 2½ feet; on this, coal with thin slate-layers, 2½ feet; yellow slate, 8 feet exposed (see Fig. 494). Twenty feet beneath it there is a small exposure of limestone.

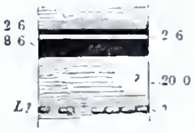


FIG. 494.

Half a mile S. of the creek, at Mr Byer's bank, it measures 9 feet in its lower member, and 5½ in its upper one, somewhat subdivided, and containing very little slate (see Fig. 495). At the next bank the upper member is 4 feet thick; and still farther S., and at a number of the openings between this place and the turnpike, it exhibits the same features.

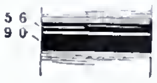


FIG. 495.—Byer's Coal.

At the turnpike, 1½ miles W. of Mount Pleasant, it yields 9 feet of coal as before; but over this are 18 inches of bluish slate, and over this again 4 feet of coal and slate, the dip being 8° or 10° E., 25° S. From hence to Jacob's Creek are numerous banks, the last being at the steam sawmill, 2¼ miles S.W. from Mount Pleasant, and not far above water-level. W. of this, it is opened high up upon the hills, as at Funk's. Stouffin's opening is in a small valley, which cuts deep into the rocks of the synclinal trough. When within 2 miles of Jacob's Creek, it is opened in the summit of a high hill belonging to Mr Mangmaugh. Hence it descends to Overholt's mill (before noticed) with a dip of six degrees.

4.—ROCKS ABOVE THE PITTSBURG COAL, SOUTH OF THE SEWICKLY CREEK, IN THE FIRST SUBDIVISION OF THE THIRD BASIN.

The limestone of the middle of the section upon the Sewickly, as was before said, descends to water-level. Above it, in the middle of the basin, the hills rise to a great height, containing another limestone stratum, and another coal-bed large enough to be worked in a number of places. Fig. 496 is designed to show these in their order; the intervals are not measured, but estimated, the lower two with a levelling instrument to assist the eye. The whole group occurs in but few hills between Jacob's Creek and the Sewickly. The section reads as follows:—

Sandstone and Slate, at the top of the highest hills, 70 feet. *Coal*, 5½ to 6 feet; Sandstone and Shale, 50 (?) feet. *Limestone C.*, 8 feet; Yellow olive Slates and Sandstones 60 (?) feet. *Limestone B.*, 8 feet; Slates, Sandstones, and Shales, exposed along the creek, 100 (?) feet. *Coal*, Sewickly, 4½ feet; Slates and Sandstones, 80 (?) feet. *Pittsburg Coal*, two members, lower one, 9 feet. Total, 387 feet.

The Sewickly Coal is opened on the N. side (see Fig. 491), and once again S. of the Sewickly at Mr Hurst's, and its outcrop repeatedly appears elsewhere.

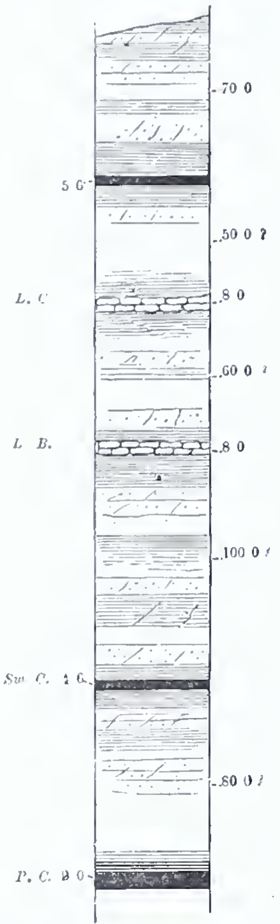


FIG. 496.—Between Sewickly and Jacob's creeks.

The limestone above it is frequently exposed along its E. outcrop, in the hills that succeed the range containing the Pittsburg Coal. Eight or nine feet of it are seen on the Clay Turnpike and near Mount Pleasant; but its outcrop does not approach Jacob's Creek very closely, owing to the denudation in that part of the basin of these upper measures. It is also frequently quarried along its W. outcrop.

The upper limestone is seldom conspicuous, and crops out only in the highest hills of the centre of the trough. It is quite a pure limestone, but its thickness is doubtful. It is exposed a short distance N. of Mount Pleasant, and near the Presbyterian Church 3 miles N., as well as in a few spots S. of the town.

The Uniontown Coal-bed (as we shall call it, though its identity is not certain) is 5½ feet in thickness; is the highest observable coal in the district: it is worked on Mr Reynolds' land, at about a mile and a half S. of the Sewickly Creek, near the summit of the highest hills along the central line of the basin.

Here it yields a somewhat soft coal, for want of a good roofing, to prevent the small quantity of pyrites which it contains from decomposing and breaking up the coal. It was also opened on the summit of the first hill S. of the Sewickly. The high hills to the W. of Mr Reynolds' bank doubtless contain the same bed, and would afford a better covering, and therefore better coal. Two miles S.W. from Mr Reynolds' it was also opened, and measured, on examination, 6 feet of coal, with much interlaminated slate. It is opened again at the high hills 2 miles N. of Mount Pleasant, and roofed by a thin brown shale; it yields 5 feet of soft coal. An exposure of limestone may be seen 400 yards N. of the bank. Near Mount Pleasant there appears to be an old opening upon the coal-bed.

The high hills S. of Mount Pleasant do not take in the coal-bed, though they frequently exhibit the outcrop of the limestone below it.

The rocks above the Uniontown Coal-bed are chiefly yellow and olive slates and shales, in some bands almost black.

5.—PITTSBURG COAL, SOUTH OF JACOB'S CREEK.

From the land on the E. side of Jacob's Creek, for half a mile below the "Chain Bridge," the Pittsburg Coal-bed has been swept away, with the exception of a small round hill, a short distance above the bridge, which is capped by it. From thence the E. outcrop of the coal-bed crosses Jacob's Creek, upon the central line of the trough, 60 feet above the water, and rises gently S. It is wrought three-fourths of a mile S.W. of the bridge, and where it crosses the road from Mount Pleasant to Connellsville, 1½ miles from the bridge. It might be worked in the hill between this place and the spot where it recrosses the same road farther on. Beyond this latter point it bears away S.W., receding constantly from Chestnut Ridge. Along this line it has been opened by Mr J. Shark and Mr G. Kelly; the coal is 9 feet thick, and the coal and slate above, 3 feet (see Fig. 497); also by several persons 4 miles N. of Connellsville, where the coal measures 9 feet, capped by coal and slate above 4 feet high on the hill at the base of which appear the variegated red-shale bands of the Barren Measures, and where Mount's Creek cuts into the trough, 2 miles from Connellsville; then leaping across the valley of Mount's Creek and White's Run, it appears on the N. side of the hills S. of the former. It crosses the Connellsville Road a short distance S. of White's Run, and is opened at the road, and again near the summit of the hill. It again crosses to the W. side of Mount's Creek, which for a mile and a quarter has scooped its valley out of rocks lying above the Pittsburg Coal-bed, the limestone far above it forming the summit-rocks of its side-hills. Where the Pittsburg Coal recrosses the creek, it forms the bed of the stream for a considerable distance. After rising to the hill-side, to

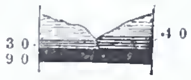


FIG. 497.—Mount's Creek.

pursue its S.W. course, it is frequently opened by citizens of Connellsville owning lands along its outcrop. It yields 9 feet of solid coal in its lower member; and the openings are so constructed that large waggons are driven into them. At one point a slide exhibits the rocks above, as expressed by Fig. 498, namely:—

Coal, 9 feet; above it blue Shale, 6 inches. *Coal*, 15 inches; Blue Shale, 7 inches; *Coal*, 1 foot; Blue Slate, 14 feet. *Coal*, 12 to 15 inches; and upon this blue Slate, 12 feet.

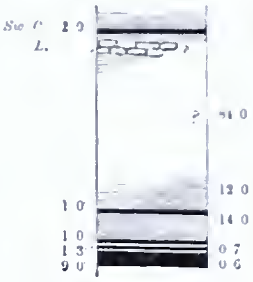


FIG. 498.—Connellsville.

The one-foot coal-bed may be considered as the Redstone Coal, but neither the Great Limestone nor the Pittsburg Limestone manifest their presence at all. In Fig. 499 thin bands of sandstone are shown above the coal.

The outcrop of the Pittsburg Coal again crosses Mount's Creek, at above one-fourth of a mile from its mouth, and then the river a few hundred yards above the point of junction of the two streams. The triangle thus cut off contains a round hill, through which the plane of the Pittsburg Coal-bed passes: this has been nearly exhausted of its coal by the Gibson Bank gangway, about 350 yards below the bridge at Connellsville. Fig. 499 gives its thickness and character, the lower bench being 9½ feet of solid coal; the upper member 4½ feet of coal and slate, with 12 inches of slate between the two.

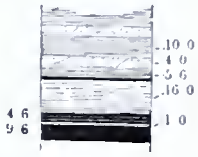


FIG. 499.—Youghiogheny River.

Upon its W. outcrop, the Pittsburg Coal-bed has been opened in numerous places S. of Jacob's Creek, at Wade and Fullerton's mill, 80 feet above the creek-level—coal usual size; and near Jacob's Creek Mill, where the creek flows directly towards the first sub-axis.

After leaving Jacob's Creek, it was opened by Mr Hurst and others along a draught coming down from the W. There is near Mr Hurst's house a single hill composed of rocks above the Pittsburg Coal, standing at the head of a valley which extends S. into the Youghiogheny at Lobinger's salt-well, 3½ miles below Connellsville. The seam is opened on both sides of this little valley. It caps a hill half a mile to the W. of Mr Hurst's, and leads its W. outcrop S. upon the Youghiogheny, 500 yards below Lobinger's salt-well. Mr Taylor opened it at 40 feet above the water-level; and other openings are made into it at different levels as it declines gently E. up the river-bank. At the salt-well it stands 4 feet above the water. The roll, once before described, lifts it again about 30 feet, and allows it once more to descend and disappear at the Broad Fording, to emerge at Connellsville.

From its disappearance at the Broad Ford, to its reappearance below Connellsville, the distance is about one mile and a fourth; but across, in a straight line from one outcrop to the other, is not more than three-fourths of a mile. It everywhere retains one uniform aspect.

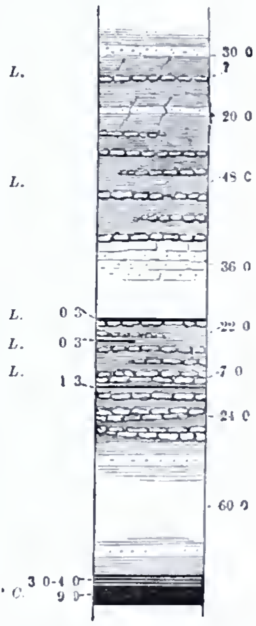


FIG. 500.—Youghiogheny River, 1 Sub., 3 Basin.

North of the Broad Fording, a ravine comes down into the valley of the river, and along its sides the Pittsburg Coal-bed has been repeatedly wrought.

The mass of rocks above the Pittsburg Coal, between Jacob's Creek and the Youghiogheny River, is not of considerable thickness, particularly on approaching Jacob's Creek. The strata immediately superposed are for the most part slates and shales, the Pittsburg Sandstone nowhere making its appearance.

The Sewickly Coal-bed shows its outcrop in a few places, as at Shoemaker's Bank upon the E. line of outcrop of the Pittsburg Coal, and above it. It is opened a little below the mouth of Mount's Creek, and is 2 feet thick, with a thin floor of slate, and beneath that a thick stratum of limestone; and its outcrop continues to be seen along the S. side of the river for some distance below Davidson's mill. Above it are slates and sandstones (Fig. 498). Below the Broad Ford it is exposed 84 feet above the Pittsburg Coal, and is 15 inches thick. It is not traceable along the W. side of the sub-basin.

The Great Limestone makes its appearance in the first hills S. of Jacob's Creek, and continues more or less exposed at intervals upon the highest middle hills to the river; but where the Pittsburg Coal outcrops at their feet, the beds of the Great Limestone cap the summits of the hills along each side of the basin. At the Youghiogheny River, interstratified, argillaceous, and calcareous layers are of great thickness (as represented in Fig. 500), and are divisible into two groups.

At the steep ledge of rocks above the Broad Ford, 35 feet of limestone alternating with slates rise above the road (itself 15 feet above the water); and upon this, sandstone and slate, coarse and fine strata, 50 feet; above this again, 40 feet of limestone; then sandstone and slate. These rocks form the cliffs of the locality.

Below the Broad Ford a section (represented in Fig. 500) was made upon a continuation of the same escarpment which overhangs the river; it is as follows:—

Slate and Sandstone 30 (?) feet. *Limestone*, unknown thickness; Sand and Slate, 20 feet. *Limestone* and *Slate* in alternate strata, 48 feet; Micaceous Sandstone, in thick and thin strata, upper part flaggy, 36 feet. *Coal*, 3 inches; *Limestone* and *Slate*, upper part black limestone with black slate, and 3 inches of coal and 5 inches of black slate, 22 feet; *Limestone*, yellow, nearly solid stratum, 7 feet; *Coal*, 15 inches. *Limestone* with *Slate*, 24 feet; Slate and micaceous Sandstone, with some black shale, 60 feet. *Pittsburg Coal*, upper and lower members, 24 feet above the river.

It is very obvious that the vast increase of calcareous matter has some close connection with the partial disappearance to the N. of the prominent Sewickly Coal-bed, and probably also with the absence of the Redstone Coal-bed beneath it. In some of the preceding sections the imperfection of the series of exposures may veil the presence of even large beds, but here the beds are evidently represented. It may be hereafter discovered that the 3-inch coal is the Sewickly Coal, and the 15-inch bed the Redstone. Upon the Sewickly Creek no limestone seems to be in connection with the Sewickly Coal. Here it lies in the midst of 50 feet of limestone and shale. At Pittsburg, Wheeling, and Morgantown, we have a recurrence of this phenomenon.

This rate of increase in the amount of calcareous matter, in the short distance from Jacob's Creek S. to the Youghiogheny River, suggests conjectures respecting the line of ancient margin of the deep water, implying that it stretched across the basin between the present lines of these two streams.

The rocks just described form the remarkable mural ridge between Mount's Creek and the Youghiogheny.

6.—PITTSBURG COAL, SOUTH OF YOUGHIOGHENY RIVER.

After leaving the flat which borders the river on its S. side, the Pittsburg Coal rises along its E. outcrop, —described when discussing the lower rocks in that section of the basin—and is opened at numerous banks belonging to various persons, and upon the Mount Braddock lands.

East of the Mount Braddock House, in the little valley at the base of Chestnut Ridge, we have the section exhibited in Fig. 501.

The strata are Limestone and yellow Slate, 5 feet; Black Slate passing into coal, 5 feet; Coal, with intervening layers of slate, 3½ feet; (Red-stone Coal?) Blue Slate, 1 foot; Yellow Slate, with limestone, and iron ore in nodules, 11 feet; Limestone, 12 feet; Blue and yellow Slate, thin coal and limestone, 4 feet; Yellow Sandstone, with thin layers of black slate, 15 feet. Pittsburg Coal, upper bench 3 feet, and lower bench 9 feet. The exposure is at the base of the hill facing Chestnut Ridge.

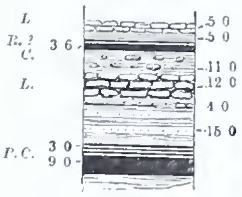


FIG. 501.—Mount Braddock.

The Pittsburg Coal is opened S. of this in four or five localities, and in the flat of Shute's Run it is opened for 1½ miles, as far as Brown's bank, at Munroe near the National Turnpike, and at water-level, on the E. side of the hill which rises from the base of Chestnut Ridge. From this point S. its outcrop is below water-level, and it is not exposed again until it crosses the wide flat of Redstone Creek, at the base of the ridge.

In its W. outcrop, S. from the Youghiogheny River, the Pittsburg Coal-bed is opened below Lobinger's salt-well, 35 feet above the water. The coal is 9 feet thick; roof, black slate, 1 foot; upper member, coal and slate in thin layers, 3 feet; olive slate, 12 feet.

From East Liberty there is a range of openings S. to the Redstone. At Oldham's the coal is 9 feet 4 inches thick. The coal exhibits a similar character at all the openings, which are numerous, and it lies with its plane so little inclined to the horizon that the openings are frequently half a mile to the E. or W. of each other, the hills being very high, and frequently cut by sharp and deep ravines, which afford abundant opportunities for drifting in upon the bed.

South of the Clay Turnpike the coal-bed is opened on both sides of Bates' or Craig's Run. At Redstone Creek it is wrought by Messrs Luckley and Carter, dipping under the creek at the opening belonging to the latter gentleman.

7.—ROCKS ABOVE THE PITTSBURG COAL, S. OF THE YOUGHIOGHENY RIVER.

The rocks which crop out above the Pittsburg Coal-bed towards the E., at Mount Braddock, are given in Fig. 501. We there see no trace of the Pittsburg Sandstone, so finely developed upon the streams farther N.

The *Sewickly Coal* is opened, as was said, on the N. side of the Youghiogheny River: it is also opened a short distance S. of the river, yielding from 2½ to 3 feet of coal; but it is not again seen until we arrive at a point 1½ miles to the S. of Mount Braddock, where it is 4 feet thick, with thin laminæ of black slate running through it, and an undermining of 1 foot of the same; the roof is soft black shale, 4 feet thick. Its outcrop is seen on the hill-side, above Mount Morey's drift, in the Pittsburg Coal, and at an elevation of about 70 feet. The presence of this bed at such an elevation justifies the assumption that the small bed at Mount Braddock (see Fig. 502) is the Redstone Coal, although its outcrop was not seen at this locality (see Fig. 503.)

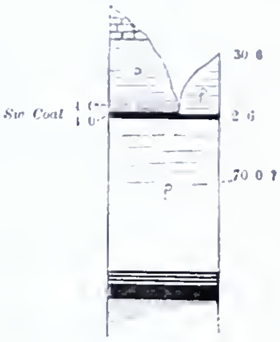


FIG. 502.—South of Mount Braddock.

This (Sewickly) Coal-bed, from 4½ to 5 feet in thickness, is opened again on the outcrop of the Pittsburg Coal-bed, at McEwan's mill. It is here a good coal, with little slate; floor, blue slate; roof, black slate 3 feet, and upon this, limestone in thick strata. This is near Shute's Run, along the hill-side of which are seen a number of old openings upon the bed. It dips beneath the water of Sharpe's Run 250 yards to the E. of the road from Uniontown to Connellsville. Above it, at this locality, lies a stratum of yellow and grey limestone, 14 feet thick.

At the National Turnpike it is opened with 5 feet thickness of good coal, and at an elevation of 84 feet above the Pittsburg Coal by measurement. It is not again opened N. of the Redstone. On the W. side of the basin are no openings upon this seam; but its outcrop, apparently of considerable thickness, occurs at the proper height above that of the Pittsburg Coal, as on the road from Liberty to Connellsville, 300 yards up the hill from Mr Dickenson's bank.

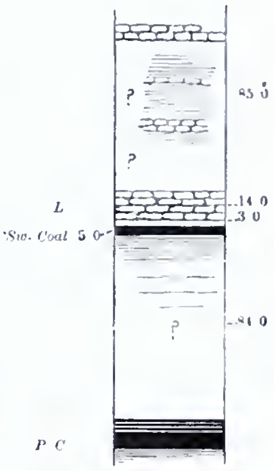


FIG. 503.—National Turnpike.

The Great Limestone, represented in two vast bands in the Youghiogheny section, continues, in the country S. of that stream, to characterise the rocks above the Pittsburg Coal. Its numerous strata are of every variety of hue and structure, and are separated from each other by yellow and bluish shales, which often enclose nodules of limestone, some of the layers of which are fossiliferous.

Fine exposures of this calcareous formation are furnished on the two sides of the trough, S. of the Youghiogheny River, as upon Mill Run, over several coal-banks at the Mount Braddock openings, Mason's bank, and elsewhere. At the latter place the limestone makes its appearance 30 feet above the Sewickly Coal-bed. At Evans's mill it rests within a few feet of the coal, and 14 feet of it are exposed; how much of the interval between it and the next exposure is made up of limestone strata, is not known. At no one point between the Youghiogheny and Redstone Creek is there an exposure from which a complete section of the whole of this calcareous deposit may be easily compiled.

Along the central line of this first subdivision of the Third Basin stand isolated knobs, of such a height as to be seen from great distances, even seducing the eye into a belief that they are but a little lower than Chestnut Ridge. Moreland's Hill is one of these. Others have also received particular names. They afford few exposures, but evidently consist of shales and sandstones high in the upper series. A few limestone strata of considerable thickness, and several unopened coal-beds, exhibit their outcrops among these strata. The summit-rocks may be considered as at an elevation of 450 or 500 feet above the plane of the Pittsburg Coal-bed. That portion of them which is above the upper division of the Great Limestone is composed of yellow and olive shales, brownish slates, a few thin layers of limestone, and a thin smut or two of coal. They generally occupy a separate range of hills, but sometimes outcrop along a continuous ascent, at the foot of which are the openings upon the Pittsburg Seam. The tops of these hills are in the central line of the basin.

The outcrop of the highest coal-bed is seen along the Youghiogheny River, but is not opened for 4 miles to the S. Here, within three-fourths of a mile of the Clay Turnpike, and 5½ miles S.W. of Connellsville, it is mined by Mr Gilcrease, and is 4 feet thick; the roof, brown slate and sand. A short distance to the E. of this place, Mr Cox opened a bed of alternating coal and slate 5 feet in thickness, resembling one opened at Mr Markley's paper-mill, upon Sewickly Creek (hereafter to be described); but the apparent height of this bed above the bed on Mr Gilcrease's land forbids their identification. The latter bed also displays a wholly different character, yielding 4 feet of solid coal, containing very little slate.

Approaching the Redstone Creek, the hills become less elevated, are separated by wider valleys of denudation, and present gentler declivities.

8.—PITTSBURG COAL, AND STRATA OVERLYING IT, ALONG THE REDSTONE CREEK, AND SOUTHWARD.

The sections exhibited in Figs. 504 and 505 were obtained from numerous exposures at and above Uniontown, upon the Redstone Creek, both by measuring and estimating the intervals; they are as follows—(see Fig. 504):—

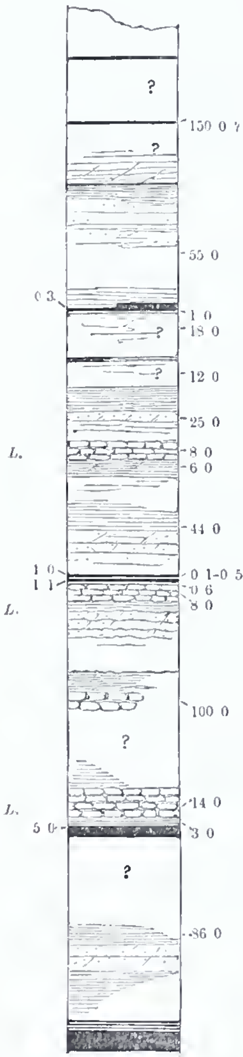


FIG. 504.—Uniontown, Redstone Creek.

From the tops of the highest hills downwards, yellow and olive shales and micaceous sandstones, with as many as three included coal-seams of unknown thickness, 35 feet apart, perhaps 150 feet. Olive Slate, and thin olive sandstone layers, soft greenish and dark-brown shale, 55 feet; *Coal*, impure, slaty, 15 inches; Blue Shale, 12 inches; Sandstone and olive Slate alternating, 18 feet; Appearance of coal, interval unknown, 12 feet; Olive Slate and grey sandstone, with black layers like coal-smut, 25 feet. *Limestone* and slate, 8 feet. Shale, yellow and bluish, 6 feet; Yellow Slate containing nodules of carbonate of iron, changing shortly into sandstone, finely flagged, and micaceous, 44 feet. *Coal*, 1 foot; Black Slate, from 1 to 5 inches; *Coal*, 13 inches; Black Slate, 6 inches. Limestone, 8 feet; Micaceous Sandstone, contorted strata; Interval, with limestone of unknown thickness; Limestone massively stratified, rough, yellow, and grey, 14 feet; Black Slate, 3 feet; Whole interval between coals measured, 100 feet. *Sewickly Coal*, 5 feet; Blue Shale floor; Interval, containing some layers of brownish slate and micaceous sandstone, 86 feet, to the *Pittsburg Coal-bed*.

The following is the succession displayed above Uniontown:—

Thick Limestone strata, 12 feet; Alternations of limestone, sandstone, and shale, thickness unknown; Limestone in thick strata. Dark-blue Slate, 15 feet; Soft-blue argillaceous Sandstone, with included layers of limestone, supposed thickness, 110 feet; Coarse grey Sandstone irregularly stratified, curled, and full of black scales. *Sewickly Coal*, 4 to 4½ feet; Soft blue Shale, 2 feet; Yellow Limestone, 6 feet; Yellow and bluish Shale, sometimes silicious. *Redstone Coal*, from 1 to 2½ feet; Blue Slate, with calcareous nodules, 15 feet; Micaceous Sandstone, 5 feet; Black and brown Shales, 15 feet. *Pittsburg Coal-bed*, lower member, 10 feet.

The Pittsburg Coal-seam itself exhibits at Mr Brownfield's bank the following upper members:—

Brown Slate, 5 feet; *Coal*, 2½ feet; *Slate* and *Coal* in thin alternate layers, with a few small nodules of iron, 15 inches. *Coal*, 1 foot; Dark-blue Shale, 1 foot. *Coal*, 12 inches; Blue Slate, 3 inches, and thin lower member.

The third coal-bed of the column (Fig. 504) is mined at Uniontown, and elsewhere in the neighbourhood, and yields a solid good coal, as at the mouth of Shute's Run. In some places its amount of contained sulphuret of iron is less than at others. By the height at which the plane of this coal-bed lies above that of the Pittsburg Seam, it will be seen that, to reach the latter at Uniontown would require a shaft about 210 feet deep.

The section of the rocks above this seam was compiled from obscure exposures upon the higher hills, and does not exhibit the character or thickness of the strata with much accuracy : it must be regarded merely as an approximation to the truth. The local bed marked 15 inches is opened some distance N.W. of the town, and yields at that point nearly 2 feet of good coal. The three thin coal-seams still higher in the series are exposed by such of the roads as cross the highest hills near Uniontown, and appear to be but a few inches thick. Whether one of these is the 5-feet bed mentioned before, as opened at Cox's or Gilcrease's openings, has not been determined ; but the probability is, that the hills where it occurs, 6 miles to the N., are much higher than those about Uniontown, though the basin itself seems to deepen S.

The Redstone Coal-bed, 2½ feet thick (shown in Fig. 505), is seen decidedly marked, and with definite relations to the coal-beds above it and below it. It is opened 2½ miles S.W. of Shute's Run. It is 45 feet above the Pittsburg Coal, and 48 feet below the Sewickly Coal. The latter bed is here irregular in its thickness ; it contains sulphuret of iron, and has resting immediately upon it an irregularly stratified coarse-grained sandstone, instead of a regularly-deposited limestone, as in some other localities. The sandstone is full of wrinkles, breaks, and thin flakes and layers of coal, in wedges and chips, exhibiting most strikingly the violence of the action upon the coal-bed previously deposited, of the agent which produced the layers of the sandstone. Without comparing the two vertical columns, the coal-bed would never be suspected to be identical at the two localities.

The space (110 feet) was estimated from imperfect data, and probably is not by any means so great ; it contains much limestone.

The layers of this great mass of limestone form, for several miles, most of the steep cliffs along the banks of the Redstone Creek.

9.—PITTSBURG COAL-BED SOUTH-WESTWARD FROM REDSTONE CREEK.

The Pittsburg Coal is opened upon its E. outcrop, at no great elevation above the water, on the land of Mrs Sutton ; also on Mr Brownfield's, at one of whose openings the irregular deposition of coal and slate in the upper member of the bed, 5 feet in thickness, is very visible (see Fig. 505). One mile S. is another opening, then another at the base of gentle hills, overlooking a wide flat to the E.

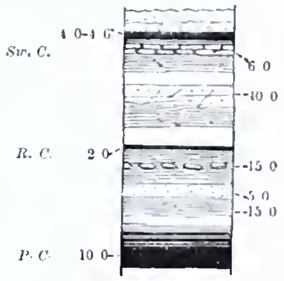


FIG. 505.—Redstone.

The ore smelted at Oliphant's furnace was formerly obtained at Mr Wynn's bank. Here the bed is 7 feet thick in its lower member ; floor, blue slate, 4½ feet thick ; then fire-clay, 1½ feet thick ; then a stratum of ore varying from 2 to 8 inches ; this is again underlaid by blue slate.—(See Fig. 506.)

This excellent iron-ore is obtained from numerous openings between Redstone and George's creeks, in roundish discs or cakes, traversed by numerous white veins of crystalline structure ; it is of a blue colour, and of fine-grained compact structure. The ore is said to have been found at Mount Braddock ; and, doubtless, examinations very easy to be made would greatly enlarge the area over which it may be profitably wrought. It is not seen, however, on the Youghiogheny, where sections have been made of all the rocks immediately under the great bed of coal.

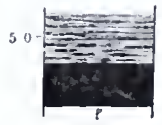


FIG. 506.—Oliphant's Furnace.

To the S. of Oliphant's furnace the Pittsburg Seam continues to recede from Chestnut Ridge, and to rise in the side of its own range of hills. It is opened one mile beyond the furnace. At Smithfieldtown its outcrop is two miles from the ridge, and has been repeatedly wrought. Thence the margin of the coal skirts the valley of George's Creek, following its Northern edge Westward, even across the first sub-axis into the second sub-basin. It is seen in the high knob between the forks of George's Creek.

South of George's Creek, along its E. outcrop, the Pittsburg Coal-bed is first opened one mile from the ridge, and separated from it by a wide valley of denudation. At the next bank (Mr Davis's) the coal is found to contain a quantity of sulphuret of iron and layers of slate. Each of these features is quite foreign to the bed in the country hitherto described. The sulphuret of iron occurs in flattened nodules, from 3 to 8 inches broad, and from 1½ to 3 inches thick.

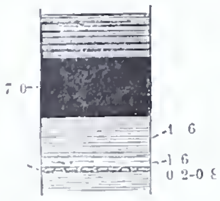


FIG. 507.—Virginia Line.

The coal is opened at intervals of half a mile by Messrs Morgan, Burchinel, and Sines, where the coal is 6½ feet thick; farther on, by Messrs Sturm, Waltg, and Morris, the last-mentioned within half a mile of the Virginia line. At all these points the openings are made high up on the hills. At Mr Rubble's bank, a quarter of a mile S. of the State line, the bed yields but 5½ feet of coal, with a few slate intercalations; roof of upper member, brownish slate, 6 feet, and above this coarse grey sandstone, 8 or 10 feet exposed (see Fig. 507).

The ore-band has here been wrought for Duncan furnace. The coal-bed itself occupies a long narrow area, at the summit of a ridge between the valleys of the Cheat River and McCulloch's Run. On the S. side of the Cheat River, an opening upon the Pittsburg Coal-seam, near the Morgantown Road, one mile W. of McCulloch's Run, exhibits an unpersistent interstratum of slate, 10 inches thick 1 foot from the floor of the bed, and 8 feet from the roof. At another opening 9 feet of coal are overlaid by 1½ feet of blue slate, and above this there occurs a thick irregularly-stratified coarse-grained sandstone (see Fig. 508). The plane of the bed is near the top of the river-hills, which are from 300 to 400 feet high. At the mouth of the Cheat River the elevation of the outcrop-level is 371 feet.

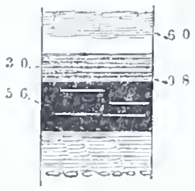


FIG. 508.—Cheat River.

On the N. side of the river it is opened at eight or ten localities, by various persons, to within 2 miles of the mouth of the river.

The vertical section of the strata of this vicinity, given in Book X. Chapter II. (see Section N.W. side of Laurel Hill, Cheat River, Virginia), constructed by Professor W. B. Rogers, is presented to show the relations of the Pittsburg Seam to the other strata as they are exposed in the gap of the Cheat River.

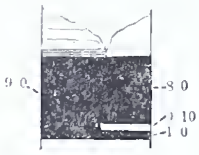


FIG. 509. — Cheat River, Laurel Hill Gap.

The openings upon the Monongahela River will be described hereafter, in following the course of that stream to Pittsburg.

Over the whole space bounded by the Monongahela and Cheat rivers and George's Creek, the Pittsburg Bed spreads in a nearly horizontal plane, and at a great elevation above the general water-level. It has been said that the height of this plane above the Monongahela Bed, at the mouth of Cheat River, is 371 feet; upon George's Creek, at its lowest probable point, it is 173 feet above the bed of the creek. The basin itself seems to rise S.W., so that the lowest point reached by the coal-bed on Cheat River is about 250 feet above the water. The relation of water-level at the three points was not measured.

The Pittsburg Coal-bed over this area not being covered by any great thickness of the upper series, is developed by all the streams and ravines of the country, and extensively mined by the inhabitants. The following openings along George's Creek, on the S. side, appeared at the time of our survey. Proceeding W. from Brown's bank, before mentioned, were T. Slenty's, Smith's, Long's (173 feet above the creek at Long's mill), containing many nodules of sulphuret of iron; Griffen's, Harden's, A. Oliphant's, G. Genty's, Crow's, Schwenzger's, Fate's, Ross's, within a mile, and Frank's, close by New Geneva.

Upon the N. side of the creek were Sutton's and Rumble's banks, opposite Long's, and below W. Griffen's, D. Brown's, Dill's, Word's, and Philip's, a mile and a half from New Geneva. This is about upon a line with the first sub-axis.

Below New Geneva, along the river, the bed is seen at the mouth of Cheat Run, still above water-level, but below that point it dips beneath the bed of the river.

10.—PITTSBURG SEAM, UPON THE FIRST SUB-AXIS, BETWEEN REDSTONE CREEK AND GEORGE'S CREEK.

It will be more convenient to take this region into consideration, before proceeding to the systematic description of the upper Coal-measures found in the second subdivision of the Third Basin, to which it properly belongs.

Upon the Redstone Creek, and on the E. side of the first sub-axis, the Pittsburg Coal-seam rises from the bed of the creek 2 miles above Middletown ; it is quarried on the W. bank by Messrs Gaddis, Gibson, and Swan. Half a mile S. of the last is Mr Springer's coal-bank on the National Turnpike, near the second milestone.

South of the National Turnpike the Pittsburg Coal is opened successively, upon its W. outcrop, by Mr Jeffers (coal 9 feet thick, and 70 feet above water-level) ; Ebhard Wood, 1½ miles from the turnpike ; and Vankirk, W. of which, at the summit of a high hill upon the line of the sub-axis, the bed is seen nearly horizontal. This point is a fourth of a mile N. of the McClellandtown and Uniontown Road, and the most N. locality, upon the first sub-axis, at which the Pittsburg Bed is seen. It is about 2 miles to the S. of the National Road. To the S. of this knob the bed has been swept away for a narrow space along the axis, the outcrops running nearly parallel, and meeting again farther to the S.

Upon the E. outcrop of the Pittsburg Seam, on the W. side of the sub-axis (corresponding to its W. outcrop on the E. side of the axis), are numerous openings S. of the National Road.

Half a mile E. of McClellandtown, the Pittsburg Coal-bed sinks beneath the water-level upon Brown's Run. It is opened by several persons within 2 miles S.W. of this ; and between this and the Masontown Road there are numerous openings at different elevations.

On a branch of Cat Run, and half a mile E. of Masontown, an exposure of the bed shows a change of character in the associated rocks (expressed in Fig. 510) ; we have,—

Limestone at the bank of the run, 4 or 5 feet ; a few feet above the limestone, *Coal*, 8 inches ; Brown Shale, some layers silicious, 22 feet ; to the Pittsburg Coal, disappearing beneath the run at the base of the hill on which Masontown is built. From a large flat here, great quantities of coal have been taken on the land belonging to Mr Rider. *Coal*, 8½ feet thick, full of sulphuret of iron, and thin slaty layers ; Blue Shale, from 12 to 18 inches ; Thin solid layer of thin carbonaceous Slate, with polished planes of cleavage ; Black Slate, 18 inches ; *Coal*, 2 feet ; Slate ; Sandstone.

Farther down Cat Run, at Johnson's mill, the coal-bed is 8 feet thick.

From the openings upon Cat Run E. the Pittsburg Coal-bed has a gentle rise until it surmounts the axis ; it is frequently opened high on the hill, not far W. of the axis, where the coal is 9 feet thick, with thin slate-layers interlaminated with the thicker bands of coal : roof, blue slate and coal, 2 feet.

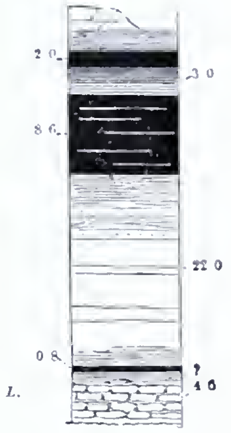


FIG. 510.—Cat Run.

The Pittsburg Coal occupies a range of higher hills upon the sub-axis, between which denuding forces have swept it away, with the rocks beneath and above it, and over so large an area that a comparatively small quantity of the bed remains. The openings are consequently few ; more of them are seen upon the road that crosses the axis just N. of George's Creek than elsewhere. But on its E. slope, beginning with the last-mentioned opening, we have a number of openings in tracing its W. outcrop. One of these, high upon the axis, shows—Coal, 7½ feet ; sandstone and shale, 2 feet ; slate and coal, 4 feet (see Fig. 511). It is seen at Showalter's, Smith's, Deiffenbaugh's, Huston's, Patton's, and Bowell's. Again at Smith's, 2½ miles W. of Oliphant's furnace, Comb's, McCormick's, Freeman's, Sturgi's, and Anderson's. At several of these banks the Oliphant furnace-ore has been obtained from beneath the coal. Some of the openings are in the synclinal trough. Many exposures of the Pittsburg Coal-bed are afforded by the deep trench of York's Run.

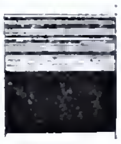


FIG. 511.—Newcomer's.

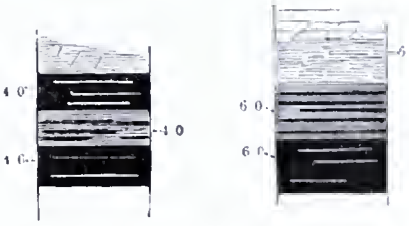


FIG. 512.—Smithfield.

Many other openings are made in it in the neighbourhood of Smithfield ; at these some interesting metamorphoses are exhibited in the structure of the bed, one of which is represented in Fig. 512, constructed from observations made at two openings, only 400 yards apart. One exhibits 6 feet of coal, with thin slate-layers as the lower member, and immediately upon it 6 feet of slate, with irregular layers of coal ; roof slate, and sandstone over all. At the other we see 4½ feet of coal, with thin layers of slate, as the lower member; 4 feet of black and blue slate, with layers of coal between, as the middle; and 4 feet of coal, with slate in thin layers, as the upper member. At one place there is quite a thick stratum of slate in the midst of the lower member.

11.—ROCKS ABOVE THE PITTSBURG COAL, SOUTH OF REDSTONE CREEK.

The columns already presented (Figs. 503, 504) give the series of strata above the Pittsburg Coal-bed, as far as discoverable upon Redstone Creek.

The first (*Redstone*) coal above the great seam has nowhere been seen by us in the country to the Southward of the stream.

The *Sewickly Coal-bed* is opened, with a thickness of 4 feet, upon Messrs Brownfield's and M^cKee's lands, and frequently exhibits its outcrops farther Southward. To the S. of George's Creek its has doubtless been wholly denuded from the surface. S. of the Cheat River it again appears.

Along its W. outcrop it has been mined by Mr Brown at a spot 4 miles to the S.W. of Uniontown, and is 5 feet thick; again, half a mile S. of this, it is from 4 to 5 feet thick; its smut is seen in places farther S., nearly to George's Creek.

A large stratum of grey sandstone, coarse-grained and micaceous, and frequently of considerable thickness, is observed to accompany the Pittsburg Coal in this part of the region, and especially where it arches over the sub-axis. This sandstone is the equivalent of the Pittsburg Sandstone, as shown in the earlier vertical columns illustrating the Conemaugh and Loyalhanna districts. The summits of the hills between George's Creek and the Cheat River are frequently capped by this sandstone and its accompanying slates, with an occasional stratum of limestone; hence the absence of the Sewickly Coal-bed.

The *Great Limestone* formation, with its accompanying shales, rises gradually along the E. and W. sides of the chain of hills in the centre of the trough, from the latitude of Uniontown southward. These hills are none of them very high, and the limestone soon forms their summits, until at George's Creek they are no longer of sufficient height to receive even its lowest members. But passing to the S. side of the creek, a limestone-bed is sometimes found at the tops of the highest knobs, which may be a relic of the great calcareous stratum.

The outcrop of the Uniontown small double *coal*, of Fig. 504, is occasionally seen Southward of that town, but it has nowhere been drifted in upon. Upon Judge Irving's land, near Uniontown, is an opening upon a 3-feet bed, full of slate and sulphuret of iron, and underlaid by 15 feet of rocks, at the lower limit of which is a bed of pure limestone 4 or 5 feet thick. This bed may possibly be the *Uniontown Coal*, which, however, has a limestone-bed immediately beneath it, as well as one at some distance.

The rocks overlying the Uniontown Coal-bed are not widely spread Southward from the National Road. One or two of the coal-beds of this part of the series, whose outcrops are noticed in the hills N. of Uniontown, occur in the highest summits S. of the National Road.

At the second ascent upon the Morgantown Road, in going Southward from Uniontown, there are exposures in the ascending order of dark-brown sandstone and olive slate. This bed of coal may be identical with the 15-inch seam shown in Fig. 504; it yields a light soft crumbling coal, and is near the summit of a hill in the central line of the basin.

Above this highest coal-bed are seen a few impure calcareous layers, found only as fragments upon the surface.

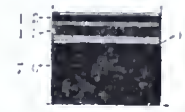
CHAPTER XXVI.

1.—SECOND SUBDIVISION OF THE THIRD COAL-BASIN WEST OF THE FIRST SUB-AXIS, S. OF THE CONEMAUGH—UPPER GROUP.

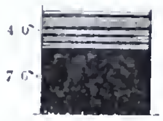
THE upper coal group, based upon the Pittsburg Coal-bed, has a narrow range in the second subdivision of the third great basin, being confined to a canoe-shaped trough along its medial line, the Northern termination of which is visible a few miles N. of New Alexandria, and the Southern about 3 miles S. of Greensburg. Even at its deepest part this trough of upper rocks contains only an inconsiderable thickness of strata.

The Pittsburg Coal-bed, whose outcrop limits the area, has been greatly denuded from the E. side of the sub-basin. In that part which lies to the N. of the Loyalhanna, it makes its first appearance at the summit of a knob 3 or 4 miles N. of New Alexandria, and a short distance Westward of the Pittsburg Turnpike. At a point S. of this it is opened 8 feet thick, and exhibits its double structure of upper and lower members, as in the previous sub-basin, to the E. It follows a narrow irregular belt, sinking gradually with the sub-basin to the Loyalhanna, where it occurs still high upon the hills near the village. The bed has not been discovered in any of the hills N.E. of it, although they seem high enough to contain it.

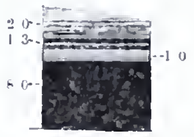
Fig. 513.—Pittsburg Coal.



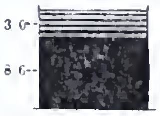
1 mile S.E. of Greensburg.



1 mile S. of Greensburg.



1 mile N. of Greensburg.



Millar's Bank, 2 miles from Greensburg.

The Pittsburg Coal-bed has been opened at about one mile Southward of New Alexandria, upon the W. side of a hill, upon the E. slope of which the outcrop appears. Several openings have been made upon it in the ravines of runs still farther South, as at Barnett's mill and Millar's bank, about 2 miles distant from Greensburg, and 400 yards N. of the Greensburg Turnpike Road. Here the lower member of the bed is 8½ feet thick, the upper member 3 feet. It is cut at George's Summit on the Pennsylvania Railroad, and is mined on the turnpike at its E. outcrop; and again one mile N. of Greensburg, where the lower member is 8 feet thick; overlaid by blue slate, 1 foot; coal, with slaty layers, 15 inches; upper member, coal and slate in confused layers, 2 feet. The bed dips N. a few degrees W., the basin rising Southward.—(See Fig. 513.)

At another opening, one mile S.E. of Greensburg, the lower member measures 7 feet in thickness; dip steep to the N.W. One mile S. of Greensburg the bed is opened on both sides of the valley of the Sewickly. It measures here 7½ feet, lower member; upper member 4 feet. One and a half miles S. of Greensburg it is 25 feet above water-level. At Mr Hammer's bank a transverse roll has thrown the bed into some irregularities of aspect, dipping it rapidly to water-level Southward, and bringing it up again with a steep counter-dip. At Shaeffer's opening it is pretty high upon the hills, and nearly horizontal. At Bear's Bank it outcrops at the S. end of its area.

Upon its Western outcrop, S. of the Loyalhanna, the Pittsburg Coal-bed is opened at the creeks, and also on the turnpike one mile W. of New Alexandria. It is here 8 feet thick in its lower member; again on a high hill E. of the White-Thorn branch of Beaver Dam Run; at Kipple's mill, where it yields 6½ feet of coal; on the Greensburg and Freeport Road; at the railway tunnel, about one mile W. of Greensburg; again, 300 yards S. from the turnpike, the coal is from 6½ to 7 feet thick (dip E. 20° S.; upper members, blue shale, 10 inches; coal and slate, 15 inches; coal, 15 inches; dark olive shale); also one mile from the turnpike, and elsewhere.

The area occupied by the Pittsburg Coal-bed has thus a width which varies from a few hundred yards to 2½ miles.

2.—ROCKS ABOVE THE PITTSBURG COAL-BED, SECOND SUBDIVISION OF THIRD BASIN.

A few layers of dark-olive slates and grey micaceous sandstone have been left resting upon the Pittsburg Coal-bed N. of the Loyalhanna. The Pittsburg Sandstone does not present itself here with such decided characteristics as in the first subdivision of the basin.

South of the Loyalhanna, the section of rocks superposed upon the Pittsburg Coal-bed (expressed in the annexed column, Fig. 514) is of greater vertical thickness; but no opportunities for examination were afforded to any satisfactory extent except along the transverse valley of the Loyalhanna, where that section was constructed or collated from road-diggings, some quarries, and a few small natural exposures: hence it cannot be relied on further than as a general exhibition of the contents of the trough, irrespective of their precise mutual relationships, as elsewhere it was found impracticable to identify the beds of slate and sandstone found here. The section reads as follows, from above downwards—(See Fig. 514):—

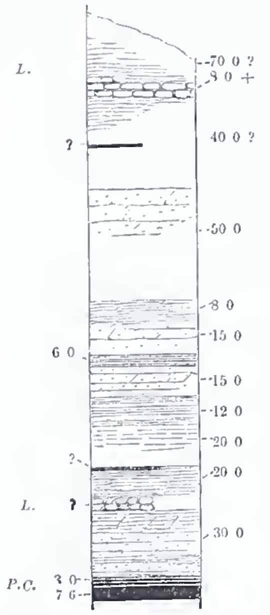


Fig. 514.—Loyalhanna, New Alexandria.

Sandstones and olive Slates, the summits of the hills. *Great Limestone,* in thick massive strata, 8 feet; exposed on the Loyalhanna, but fully developed by the tunnel and cuttings of the Pennsylvania Railroad, at and near Greensburg, 30 to 40 feet. Interval, containing a thin coal-outcrop, 40 feet. Sandstone in flags and massive strata, 50 feet; Yellow Slate, 8 feet; Coarse grey Sandstone, 15 feet. Blackish Slate, 6 feet; place of Sewickly Coal (?) Micaceous Sandstone in thin layers, 15 feet. Black Slate, with sandy layers, 12 feet; Brown Shale, 20 feet. *Coal* outcrop; Redstone Coal-bed (?) Yellowish and bluish Shale, with thin limestone layers in the lower part, 20 feet; Silicious Slate and flaggy sandstone, 30 feet. Pittsburg Coal-bed—upper member, Coal and Slate, 3 feet; lower member, 7½ feet.

The uppermost bed of the great calcareous deposit is sometimes quite a pure and fossiliferous limestone, in thick layers; it is found at the tops of many of the central hills—for example, it has been quarried at the summit of one a little East of Greensburg. Another and lower limestone, the precise place of which could not be determined in the section, repeatedly appears at the base of such hills as exhibit the upper limestone-stratum at their summits.

The Sewickly Coal-bed only indicates here its proper position by black slate, although it is well developed S. of this upon the Sewickly Creek.

From the S. point of the Greensburg area of the Pittsburg Coal, to New Staunton on the Big Sewickly, nothing is to be seen but the Barren Measures, which afford occasional traces of a coal-bed upon their hill-sides.

CHAPTER XXVII.

ALLEGHANY AND MONONGAHELA RIVERS, IN THE NEIGHBOURHOOD OF PITTSBURG.

Descending the Alleghany River from the mouth of the Kiskiminetas, we meet with the rocks in an ascending order, the upland on each side being occupied by the Barren Measures.

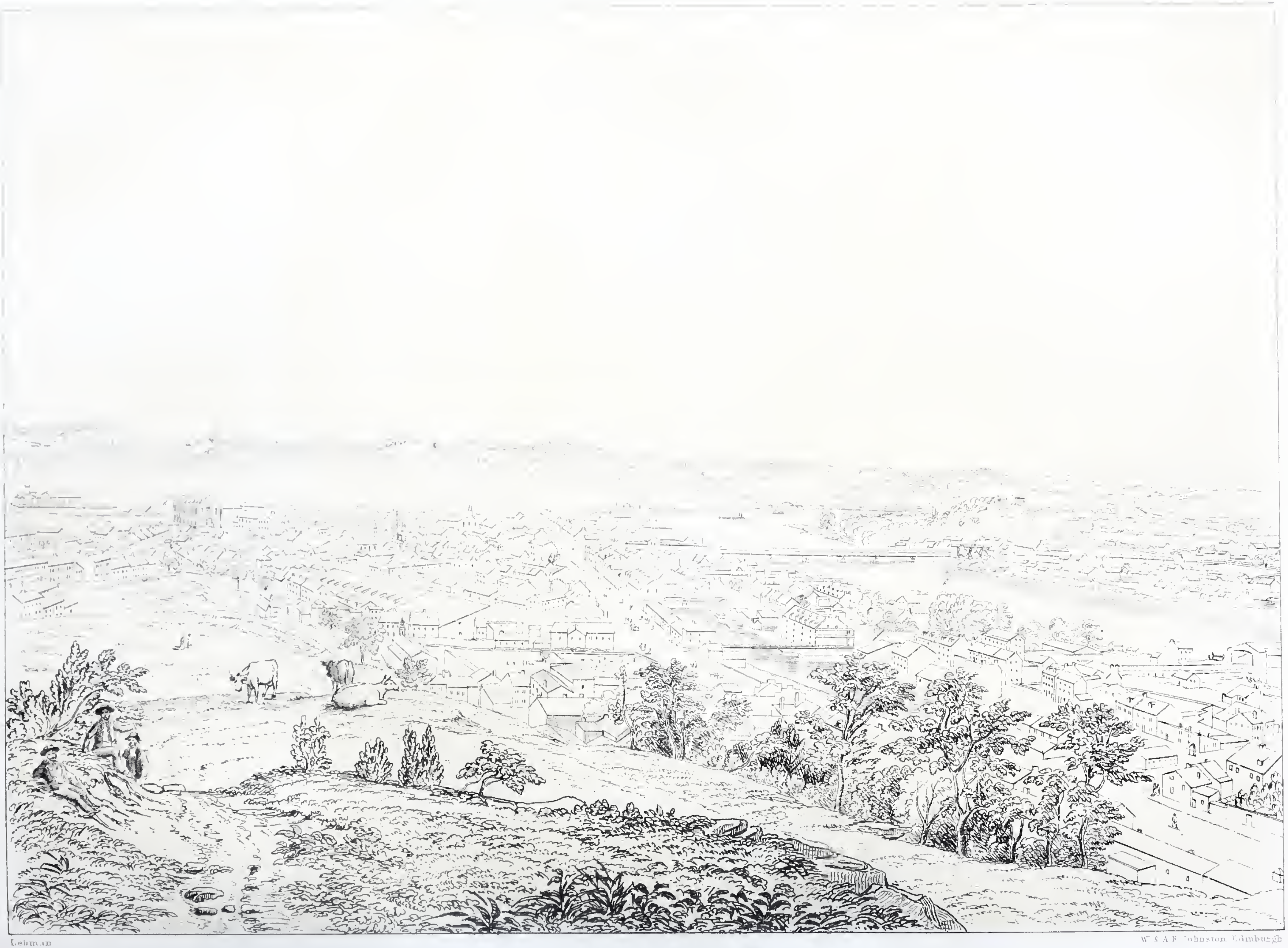
The Lower Freeport Coal, 57 feet above the water at *Freeport,* gradually subsides to the level of the river, which it reaches at about 2 miles above Tarentum, varying in the interval between a maximum thickness of 4 feet and a minimum of 2 feet.

The Upper Freeport Coal, after being exposed by various cuttings of the Alleghany Valley Railroad, disappears beneath the water-level 3 miles below Tarentum; near which it is mined at an elevation of 30 feet, though it shows itself on Pine Creek, about 2½ miles from the river, exactly on a level with the stream. It is here 6 feet thick. At Peterson's salt-well, one mile below Tarentum, it is of the same thickness, being opened beneath a bed of shale, at an elevation 25 feet higher than at half a mile farther down the river. At Kier's salt-well, a short distance above, it is 7 feet thick, and is mined 40 feet above the level of the river. At Tarentum it is opened at Donnelly's salt-well, and in several other places on both banks of the river, within 3 miles of which it is also mined on Bull Creek. At Freeport it is 144 feet above the water.

The Freeport Limestone, though often regularly stratified, consists more generally of a stratum of nodules imbedded in shale, but even these yield a good ash-coloured lime.

Below the town of Freeport, between the Mahoning Sandstone and the Upper Freeport Coal, there lies a mass of shales from 2 to 20 feet in thickness.

The Mahoning Sandstone forms a double set of cliffs along the river-slopes from Freeport to Tarentum. It consists of two massive members, each 35 feet thick, and separated by 25 feet of shale. A band of quartzose conglomerate, 4 feet thick, occurs at the base of the upper member, imbedding nodules of iron, and sometimes overlying a 6-inch bed of slaty coal, which is to be considered as the representative of the Elk-Lick Coal-bed.



Lehman

W. & A. K. Johnston, Edinburgh

PITTSBURG IN 1840, FROM GRANTS HILL.

The rock forms much of the surface-land of the S. parts of Armstrong and the N. parts of Alleghany counties.

A second Barren-Measure Coal-bed, to which we give no name, overlies this Mahoning Sandstone in the river-hills, 15 miles above Pittsburg (compare Fig. 394, at Alleghany Furnace), and is 1 foot thick. It traverses the N.W. corner of Westmoreland County.

Above it are yellow and brown shales, which graduate upwards into a mass of slaty argillaceous sandstone, forming at Sharpsburg the lowest rock seen at water-level; it is well exposed at the mouths of Girtie's Run and Pine Creek, and in most of the ravines between Pittsburg and Tarentum. It also appears at the mouth of Saw-mill Run upon the Ohio River.

At Pittsburg we find, at the base of the hills which overlook the city, a bed of variegated calcareous shale, of a peculiar mottled appearance, its lower portion reaching down nearly, if not quite, to the brink of the Ohio River. It is a bed of considerable thickness, and consists of two varieties, the one blue and the other bright purple or red, irregularly intermixed in spots, blotches, and bands. The blue variety lies sometimes in continuous layers. It is soft and calcareous, sometimes without any regular cleavage, and exists throughout as a rather homogeneous mass, very friable, and easily crumbled by the weather. Dispersed through it are numerous calcareo-ferruginous concretions lying in irregular layers, and occasionally so abundant as to constitute a considerable part of the whole bed. They are of all sizes, more or less ferruginous and excessively hard. Some minute fossils have been detected in this stratum, but it is generally not fossiliferous. The quantity of calcareous matter diffused through the shale is such, in fact, as to warrant our considering it an impure *marl*. From Pittsburg it may be traced along the W. bank of the Alleghany River to some distance above Sharpsburg, rising N. On Thompson's Run, a branch of Turtle Creek, 14 miles E. of Pittsburg, it is met with, forming the base of the hills at nearly the same elevation as at that city.

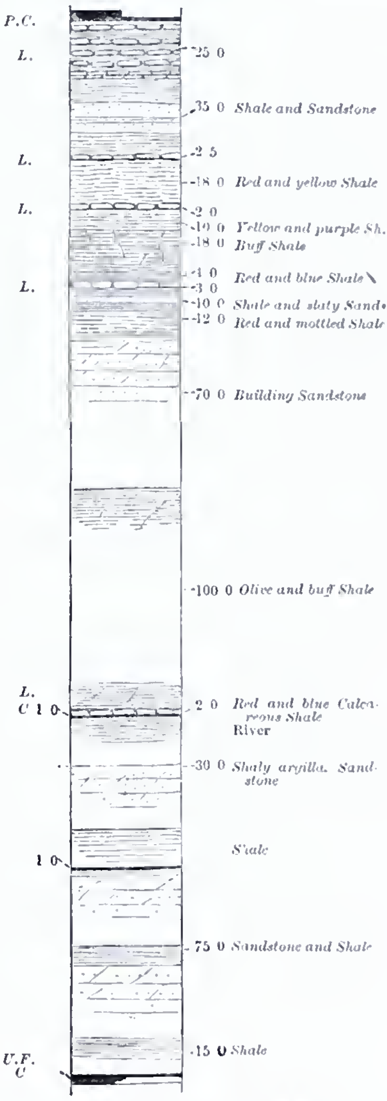

P.C.
L.
25 0
35 0 Shale and Sandstone
L.
2 5
18 0 Red and yellow Shale
L.
2 0
10 0 Yellow and purple Sh.
18 0 Buff Shale
4 0 Red and blue Shale
L.
3 0
10 0 Shale and slaty Sandst.
12 0 Red and mottled Shale
70 0 Building Sandstone
100 0 Olive and buff Shale
L.
C 1 0
2 0 Red and blue Calcareous Shale
River
30 0 Shaly argilla. Sandstone
Shale
1 0
75 0 Sandstone and Shale
15 0 Shale
U.F.
C

FIG. 515.—Type of Strata at Pittsburg.

The coal of the Barren Measures resting on the above is a thin seam varying in its thickness from 6 to 18 inches, and of good quality. It is hard, black, and brilliant. One foot is about its average thickness.

Black Fossiliferous Limestone.—This is a dark-grey or black limestone; when first exposed it is extremely hard, effervesces freely when treated with an acid, and is remarkable for the abundance, though not the variety, of the fossils diffused through it: these are principally bivalves, species of Producta, Leptena, Terebratula, &c. Joints of Encrini are also very abundant, from one-sixteenth to half an inch in diameter, the column being composed of crystallised carbonate of lime, which has a handsome appearance when freshly broken. Another very abundant and characteristic fossil is a species of Orthocera, from half an inch to two inches in size, often abundant on the surface of the rock. Ammonites have also been found in it. When exposed near the base of the hill, this stratum forms a shelf above the small coal-bed; it is of a brownish-grey colour, and outward slaty structure. If judiciously selected it will make a good lime, and has been used for the purpose on the Mechanics' and Farmers' Turnpike at Pittsburg. In company with the preceding strata, it rises to the N. along the course of the Alleghany River. It has been detected in Indiana, Wilkins and Versailles townships, Alleghany County, and in Washington and Unity townships, Westmoreland County, and on the Kiskiminetas, below Saltzburg. Thickness about 2 feet.

The next stratum ascending is a heavy deposit, consisting of shale, passing into slate, with sandstone layers. The lower portion is a soft shale of a drab or yellowish colour, regularly laminated, and decomposing into a stiff clay. Nodules or concretions of compact, fine-grained, and tolerably pure limestone, are dispersed through it. It passes into a heavy slate of blue, yellow, and black colour. It is slightly micaceous, contains a good deal of sand,

and splits into plates, somewhat resembling roofing-slate. Upon this, in some places, there is a thick bed of slaty sandstone, passing gradually into a smooth slate. The sandstone layers are sometimes very compact and heavy, at others separated by bands of shale. The dark-coloured portions of the stratum are generally fine-grained, have a ready cleavage, and contain impressions of plants. Plates may be obtained 2 feet square, beautifully marked with these remains of an ancient vegetation. These are not found in the hard silicious upper layers. The whole mass is sometimes divided in a vertical direction by joints, which separate it into prismatic blocks, and impart a picturesque appearance to the exposed portions. Layers of calcareo-ferruginous concretions are found running through it parallel to the cleavage. They are generally round and rough or knotty on the surface, and from 2 to 4 inches in diameter.

The upper part of this bed, immediately beneath the overlying stratum, differs frequently in appearance from the rest. It is much softer, is red or yellow in colour, and slightly ferruginous. The hard silicious portions afford an abundant supply of good flagstones. The dark black bands have been mistaken for the soft shale accompanying the coal.

This member of the series may be traced generally along the watercourses throughout Alleghany County, and is exposed in Unity and Franklin townships, Westmoreland County. Thickness by estimation, 100 feet.

Grey Sandstone.—Upon the above there rests a valuable and important deposit of sandstone. The lower portion is very solid and compact, affording an excellent material for building, while the upper portion is generally too slaty and too much broken to be used for this purpose. The prevailing colour is a light grey, with a yellowish tinge; in some places it is brown and brownish green. It varies in composition as much as in colour, but generally admits of being easily dressed, and of being readily split into prismatic blocks. Some portions are remarkably micaceous, in others the mica is entirely wanting. Occasionally it is not fit for masonry, being too friable, and crumbling too freely on exposure to the atmosphere, chiefly in consequence of its containing in these cases a considerable proportion of clay. In this rock the lines of deposition are very manifest, forming beautiful curves, and accurately representing the eddying currents by which the fine sand was originally deposited: these are most evident where a brown layer interposes itself between the lighter-coloured rocks. Imbedded in the lower parts of the mass are great quantities of pebbles, which differ in colour and composition from the material of the surrounding sandstone; they consist generally of a drab or a bluish-coloured clay of a fine texture, and contain minute specks of mica; they are from 1 to 15 inches in diameter, but always rounded, and apparently water-worn. The question of their origin suggests some interesting inquiries.

The lower part of the stratum contains also thin seams of vegetable remains. These fill the joinings of the layers, and are composed of black carbonised matter, which in some instances assumes the condition of a pure coal. They are slaty, friable, and emit a bituminous odour when freshly broken. These impressions are generally so interlaced and compressed together, that it is difficult to distinguish their forms; now and then, however, distinct figures are traceable from 6 to 8 inches broad, and with curved stems of considerable thickness.

In many situations this rock is soft, crumbly, and granular, consisting of rounded grains of sand of a dark green, and sometimes a brown colour, passing into a ferruginous reddish tint. This change of colour depends upon the quantity of iron present in the rock, and the stage of decomposition to which it has arrived. The grains are of pure white quartz, evidently water-worn, and united by a calcareous cement, particularly in the green and brown varieties. In the former, some minute fossil univalve shells have been detected.

This rock is sometimes met with in a state of complete decomposition in the form of a coarse sand. Certain layers are yellow, others bright red, with intervening layers of grey sandstone, which, containing but little iron, have resisted decomposition. In these cases the thin flakes of the vegetable remains have been replaced by layers of black clay and sand; the rock in this state is too friable to admit of being transported. The upper part of the main stratum into which the preceding passes, is generally very schistose, with irregular laminations, and presents a broken, shattered appearance; it is sometimes very full of nodules, which are chiefly concretions of an impure iron-ore. This stratum affords an abundant supply of building-stone to the city of Pittsburg. The sandstone employed in the construction of the court-house, the Western Penitentiary, and other public buildings, and also some private edifices, belongs to this member of the series. It is quarried in many places on the Monongahela, along the banks of which it may readily be traced, until it sinks below the water-level. Medium thickness, 70 feet.

Red Shale.—This is a bed of red and marly shale, internally blue and mottled, resting on the schistose part of the preceding stratum, and forming in the hill-sides a well-defined belt of a bright red or purple colour. It is in general imperfectly laminated, slightly calcareous, and contains traces of fossil shells. It is not exposed on the hills immediately around Pittsburg, but may be observed on the level or slightly undulating flat upon which East Liberty is situated. It extends widely through Alleghany County. The thickness averages 12 feet.

Above the red-shale stratum are blue or yellowish-green slates marked with ferruginous discolorations, and also layers of sandstone. Where these predominate, the rock is a coarse slaty sandstone. Thickness, 10 feet.

Non-fossiliferous Lowest Limestone of the Barren Measures.—This is a well-defined stratum consisting of a hard yellowish or buff-coloured limestone, jointed into square blocks. It effervesces freely, gives out an argillaceous odour, and is marked with transparent specks of crystallised carbonate of lime. It probably contains too much oxide of iron and argillaceous matter to yield a good lime. For weight and hardness it is quite remarkable. Although frequently exposed along the hill-sides, it is not easy to trace, as it is very apt to be covered up by the matter from the overlying shales. Thickness, 3 feet.

Upon the limestone rests a stratum of red and blue shales, distinguished by its want of tenacity, its bright colours, and smooth cleavage. The red and blue portions are irregularly intermixed. This is one of the coloured shales which give the red and variegated appearance to the lower part of this series, and may be met with on the sides of the hills and ravines throughout Alleghany and the N. part of Westmoreland counties. Around East Liberty this and the next stratum are found on the surface of the remarkable flat on which that suburb is situated, in many places decomposed, and forming a red soil. Thickness, 4 feet.

Above the red shale are buff and olive shales, 18 feet thick; still higher, yellow and purple shales. The lower portion of these is frequently of a dark purple colour, and is very soft and not well laminated. The prevailing colour is yellow. They are frequently exposed on the sides of the runs and watercourses. Calcareous nodules are scattered through them, sometimes constituting the largest portion of the stratum. Thickness, 10 feet.

Second Non-fossiliferous Limestone of the Barren Measures.—Upon the preceding is a thin bed of limestone resembling that last described in appearance and composition. Blocks of it are frequently scattered along the base of the hills, having fallen down from the washing away of the underlying bed of shale. Thickness, 2 feet. Over it lie red and yellow shales, soft and friable, and containing a few calcareous nodules. Thickness, 12 feet.

Third Non-fossiliferous Limestone of the Barren Measures.—This is a conspicuous and widely-expanded bed of limestone, from 3 to 5 feet in thickness; it is yellow on the surface, though internally its colour is dark blue. It breaks off in square or oblong blocks, which are hard and heavy. Portions of it might perhaps receive a good polish. By the decomposition of the underlying shales, it is often found tumbled down at the base of the high hills which enclose the Monongahela and Youghiogheny rivers, along whose shores its fragments are abundant.

Over the limestone occurs a thick and important deposit of shale and sandstone, extending up to the next bed of limestone, or that which underlies the main Pittsburg Coal-seam. It is perhaps 30 feet thick. It may in almost all cases be seen where the coal itself is exposed, generally in the character of a grey slate, well laminated with interspersed sandstone layers, varying from a few inches to several feet in thickness, and separated by soft bands of shale. The upper part of this stratum adjacent to the limestone is frequently very soft and friable, abounding in calcareous nodules, irregularly dispersed throughout the mass. Occasionally, but not very often, the sandstone layers increase in number and thickness with a corresponding diminution of the shales, giving rise to a sandstone sufficiently compact to be employed in building. It is quarried for this purpose in the vicinity of Pittsburg, though more usually its principal useful application is in supplying much excellent flagstone, which it readily affords, of large size and very smooth surface. This stratum extends through the valley of the Monongahela from the foot of Chestnut Ridge to the W. boundary of the State, obeying the general inclination of the accompanying strata, and exposed in corresponding situations. The sandstone layers very frequently exhibit "ripple-marks," disposed with great regularity, showing that the rock was deposited from a rather gentle current, and probably in a shallow sea. Impressions of plants are not uncommon. Thickness by estimation, 30 feet.

Pittsburg Limestone.—Resting on the above, and immediately underlying the Pittsburg Coal-seam, is a bed of blue and black limestone, in layers from six to ten in number, separated by shale, the whole measuring about 25 feet. One of these layers is generally found immediately under the coal-seam, succeeded by the principal body of the shale, beneath which are the remaining layers of limestone in a close and continuous stratum. These layers are from 1 to 2½ feet in thickness, and vary in their colour, which is generally dark blue, though in some cases it is a deep black, and then the rock is ferruginous, and gives out a bituminous odour. When there is a deficiency of calcareous matter, the upper layer adjacent to the coal-seam is wanting, and its place is supplied by a layer of excessively hard calcareous nodules called "Nigger-heads" by the miners, and which are imbedded in the usually intervening shale.

Pittsburg Coal.—This consists of three parts: first the main breast of coal, and above this a layer of clay, and over this again a bed of coal, forming the roof. The former of these rests upon the limestone, from which it is generally separated by a few inches of blue clay or decomposed shale.

In the neighbourhood of Pittsburg the lower part of this mass, for about 1 foot in depth, abounds in thin seams of pyritous shale, and is hence rejected by the miners. Above the main seam there is a stratum of blue or black clay-shale, dividing it from the coal roof. It is hard and compact when first dug out, but on exposure to the atmosphere crumbles down into a soft clay. It is generally free from gritty particles, and has, with a similar layer in the coal next the roof, been advantageously used in the manufacture of fine bricks. Above it is the roof coal, consisting of a bed of coal with shale intermixed in numerous thin layers. Towards the bottom this is a band of true coal from 1 to 2 feet thick; the higher layers are generally thin. The coal in this part of the seam is in itself of good quality, but the expense of separating it from the accompanying slate is generally too great to justify the attempt: hence the miners along the Monongahela content themselves with extracting the lower division, leaving the remainder to form the roof of their drifts. In Alleghany County the main breast varies from 5 to 6 feet in thickness. The quantity of pyrites in the clay and shale accompanying the coal is very considerable; these layers readily crumble, and when exposed to the atmosphere are generally covered with *copperas*, produced by the chemical action upon the sulphuret of iron. These natural encrustations of copperas are very common throughout the district. In many instances the coal of the roof has been precipitated, by a slipping of the hill-side, upon the lower part of the seam, in which case the latter has often taken fire from the heat evolved by the chemical decomposition just mentioned. This has occurred particularly at the mouth of Redstone Creek, in Fayette County, where the overlying shale has been baked and reddened by the combustion, and hence the name of the stream. The shale and clay of the upper part of the seam abound in casts and impressions of plants, many of which are very beautiful.

The Northern outcrop of the Pittsburg Coal is about 5 miles N. of Pittsburg, passing through the highest hills in the N. parts of Westmoreland County and that part of Beaver which lies S. of the Ohio River. In the neighbourhood of Pittsburg, the coal at the summits of the hills is overlaid by a bed of brown friable and compact shale of a ferruginous appearance, enclosing sandstone layers of greater or less thickness, which, increasing, as we ascend, in number and size, pass gradually into a compact sandstone. In the N. part of the district this stratum is remarkable for the quantity of mica that it contains, which causes the sandstone layers to split into large slabs with a glittering micaceous surface, and imparts to them at the same time a crumbling texture. In other situations it abounds in vegetable impressions, apparently the stems of arundinaceous plants, &c. Very frequently, particularly in the lower part, it is a very soft brown and black shale, readily disintegrating, and has a splintery fracture, breaking off in long thin prismatic fragments like the splinters of decaying wood. The surface is often covered with an efflorescence, a part of which is copperas. There are two varieties of this encrusting matter—one is a salt of a pure white colour in delicate crystals, and a greenish-yellow mass, into which the former passes by longer exposure to the atmosphere. The whole stratum varies much in its dimensions, being in some places very thick, and in others only from 5 to 10 feet. It may, however, be estimated at 30 feet of average thickness. It does not contain the Redstone Coal-bed.

Above this occurs the Pittsburg Sandstone about 25 feet thick, and the shales 20 feet, upon which lies the Great Limestone.

The Great Limestone.—This bed may be traced from the vicinity of Pittsburg continuously up the Monongahela to the Virginia State line. It is a non-fossiliferous deposit, no fossils having been hitherto found imbedded in it, notwithstanding the frequency with which it has been examined in tracing its range through the country. The variation in the thickness, and particularly in the composition of the stratum, is remarkable. It consists of numerous beds of limestone separated by thin seams of shale. These beds are sometimes in contact, at others they include thin layers of shale from 1 to 8 feet in thickness. Instead, however, of these partings of shale, we occasionally meet with dividing-bands, consisting of a sandstone which is calcareous, effervescing slightly with acids, and passing sometimes insensibly into the limestone.—The limestone itself is generally of a blue colour of various shades, is excessively hard, and breaks with a semi-conchoidal fracture. At other times the layers are black or light yellow, and contain transparent specks of crystallised carbonate of lime. The latter variety is frequently very beautiful, and apparently hard enough and fine enough in texture to receive a good polish: it would make a handsome ornamental marble, although the thinness of the layers would interfere with its extensive use for architectural purposes. The black kind is very hard, of a slaty structure, and gives out a fœtid or bituminous odour when bruised or struck. This kind is generally found in contact with the interposed black shale. In some instances it passes insensibly into it, when the shale becomes a black calcareous slate, splitting readily into smooth plates, and effervescing freely when touched with an acid. Most generally the shale is very soft, of a deep blue or yellow colour, imperfectly laminated, and decomposing readily into a soft clay. Not unfrequently it contains layers of calcareous nodules. Occasionally it is very soft and black, resembling the outcrop of a coal-seam. In the S. part of the district, instead of shale we find two thin layers of *coal* separating the limestone-beds. The largest of these is 2½ feet thick, and has been opened in several places as a *coal*-seam.

This well-characterised member of the series is readily recognised, and is very generally exposed in the ravines and hill-sides; but being a rather variable mass as regards its minuter features, it is by no means easy to ascertain in every case its precise composition. The quarries established in it are generally mere uncoverings of the upper layers. Such is the case with those in Wilkins and Monongahela townships, Alleghany County, where the rock seems to thin off towards its N. outcrop.

In Alleghany and the N. part of Westmoreland counties it is met with, covering the highest hills with its lower layers. These are sometimes seen capping the insulated summits of the hills, and forming a natural pavement, completely detached from the surrounding strata. Advancing towards the S., we find it gradually sinking under the hill-tops, and showing itself lower down on the sides of the creeks and small streams, and becoming at the same time thicker.

There are but few of the streams, or even small runs, emptying into the Monongahela from Elizabethtown to the Virginia line, along which this stratum is not well exposed, its beds either forming a series of horizontal steps or platforms in the smaller watercourses, or steep and smooth escarpments on the hill-sides. On its almost incalculable value to the agriculture of our S.W. counties, I need not dwell; but I cannot refrain from expressing a sincere regret that the importance of lime as a fertiliser should continue to be so much overlooked. It is proper in this place to observe, that the shales between the limestone-beds themselves are frequently very calcareous, and are consequently, in many cases, genuine *marls*, both as respects their composition and their agency upon the soil.

CHAPTER XXVIII.

THIRD SUBDIVISION OF THE THIRD GREAT BASIN SOUTH OF THE GREENSBURG AND PITTSBURG TURNPIKE.

The Pittsburg Seam, in the Third Subdivision of the Third Basin, is cut on its E. outcrop on the Pennsylvania Railroad, about 1 mile W. of Grapeville Station, and is opened upon the Greensburg and Pittsburg Turnpike, half a mile E. of Adamsburg, with a gentle W. dip. In the neighbourhood of Irwin's it is extensively mined by the Westmoreland Coal Company. At this point it dips very gently Eastward.

Tracing the outcrop S. from the turnpike, we find it opened on the lands of Mr Bess and others: coal, 7 feet thick. It is opened at numerous places farther S. and at Taylor's mill, all within 4 miles of the turnpike. The latter is half a mile E. of Madison.

Between this and the Sewickly Creek the bed has been opened sometimes on the E., sometimes on the W. side of the hills that contain its last E. outcrop in this subdivision. Upon the hills of the creek, and 80 feet above the water, it is mined at Kiefer's old bank, where a bed of limestone is seen 15 feet below the coal.

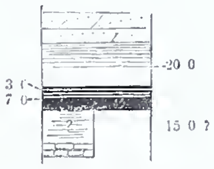


FIG. 516.—Sewickly, (Markle's Paper-Mill.)

This range of openings is W. of the termination of the second sub-axis. From the country E. of them the bed has been swept away, its outcrop sweeping S. from the point where it crosses the Sewickly at Kiefer's, and then S.E. to range along the side of the first sub-axis.—(See the Map.)

Eight feet above the water, upon the S. bank of the Sewickly, the Pittsburg Coal-bed has been opened at Markle's paper-mill.—(See Fig. 516.)

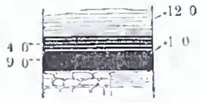


FIG. 517.

As the outcrop ascends the hills in a S. course towards the Mount Pleasant Turnpike, it is opened within half a mile from the turnpike, and exhibits a thick coal-seam, and limestone below it 6 feet in thickness. (See Fig. 517.) It is again opened on the turnpike road, 9 miles from Mount Pleasant, and frequently between this point and the Youghiogheny along its E. outcrop.

S.W. of the same point, between it and the river, in a space of 2½ miles, it is also opened in several places. Most of the openings are in the draught running down S. to Smith's mill, on the Youghiogheny. Within three-fourths of a mile from the river are Frick's, Shoop's, W. & S. Rhode's openings; and on the N.E. shore of the river, about 1 mile below the mouth of Jacob's Creek, is Porter's bank. Near this the bed crops out on the top of the hills. Anderson's bank, 300 yards from Porter's, is not high above water-level, and a short distance below this the bed ascends beneath the bed of the Youghiogheny.

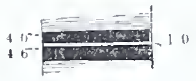


FIG. 518.

Returning to the Pittsburg Turnpike, and descending the Youghiogheny River, we find the Pittsburg Coal-bed opened at the top of the hill, 17 miles from the latter city, and measuring as in Fig. 518:—

Roof, Shale. *Coal*, 4 feet; Clay, 1 foot; *Coal*, 4½ feet.

Ten and three-fourth miles from Pittsburg, the Pittsburg Sandstone has been quarried; it is a yellowish-grey coarse sandstone, slightly micaceous.

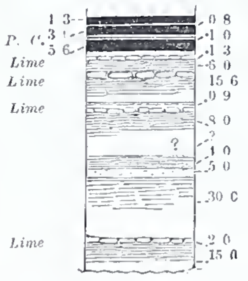


FIG. 519.—Turtle Creek.

Half a mile E. of the latter, and perhaps 30 feet below the hill-tops, is a coal-bank (Pittsburg Coal), which gives the following section:—

Shales and Sandstone, 10 feet; *Coal* and Shale, 15 inches; Clay, 8 inches; *Coal*, with thin slate, 3 feet; Clay, 1 foot; *Coal*, 5½ feet. Interval, 2 or 3 feet; Limestone, blackish, 15 inches; Slate and sandstone, 6 feet exposed.

Continued downwards, the section shows further some thin limestones. That marked 9 inches in the section is peculiar, of a dark-green colour, granular and speckled, resembling some of the bands of the Umbral Limestone on Chestnut Ridge; then come purple shales, as at Pittsburg, until we reach the fertile wide flat of Turtle Creek.

Descending Turtle Creek 1½ miles to Funk's mill, a white cliff of sandstone is seen overhanging it, and this is the last-mentioned sandstone of the above section ; it is light-grey, homogeneous, micaceous, with dark, smooth, ferruginous nodules, and at a height of 50 feet above the water ; under it are shales, 30 feet thick. Beneath these last is a bed of Fossiliferous Limestone, 2 feet thick, dark-grey and slaty. This again lies upon soft yellow shale in the creek.

The purple shales are very persistent along the creek. The Fossiliferous Limestone crops out from the bank of the creek half a mile above the bridge, 2 feet thick, of a greenish-grey colour, and full of fossils. The red shales above it effervesce with acid, and contain minute fossils and concretions. This is 25 feet above the water of the chief branch of Turtle Creek. In the hill over it a heavy sandstone stratum crops out.

McCulloch's bank is 13½ miles from Pittsburg. The upper member of the coal, 3 feet thick ; the lower member, 6 feet. Shales and slates continue for 40 feet to the summit of the hill.

On the hill-tops bordering the Monongahela River on the S., and the Pennsylvania Railroad on the N., there are numerous openings upon the Pittsburg Seam, from which large amounts of coal are extracted. The coal is lowered from the mines upon inclined planes, and loaded upon boats on the river.

At the road to McKeesport the Pittsburg Coal is opened on the S. bank of Turtle Creek, 1½ miles from the river, and at the same elevation as upon the river opposite that town. It is probable that the Fossiliferous Limestone, which we have above described, will be found in all the deep runs which descend to the river in the neighbourhood.

FROM McKEESPORT TO ROBBSTOWN (WEST NEWTON) ALONG THE YOUGHIOGHENY RIVER.

At the mouth of the river an alluvial flat occurs upon the N. side, from which the hill-sides rise steeply, exhibiting a line of low cliffs formed by the sandstone stratum above the Fossiliferous Limestone. A mile farther up, where it is 50 feet above the present water-level, it shows unequivocal marks of the action of flowing water.

Two miles from the mouth, the bottom is half a mile in width, and the hills are low, and frequently cut down by side-ravines. Here is Craven's salt-well, 460 feet deep, which emitted large quantities of carburetted hydrogen gas.

No written account was kept of the borings, but the following details are remembered :—

Coal, 12 feet (?) thick, the Elk-Lick bed, bored through at a depth of 75 feet. This intimates the presence of a bed, with top and bottom slates ; again *Coal*, 2½ feet thick, at a depth of 400 feet.

In a creek, which enters the river half a mile above this, is seen a thin band of a fossiliferous limestone, and over it 3 inches of carbonate of iron in nodules.

Around Graham's mills, and 100 feet above the present water-level, lie great water-worn blocks of sandstone upon the hill-sides.

Where the road crosses the hills to descend again to the river, the country exhibits exposures of the Pittsburg Coal, with the coal and limestone strata above it. The Uniontown (or Sewickly) Coal just enters the tops of the hills. An exposure of the Pittsburg Coal is seen descending the ravine to the river : *Coal*, 1 foot ; clay, 9 inches ; *Coal*, 3 feet ; clay, 8 inches ; *Coal*, best, 6 (8 ?) feet exposed (see Fig. 520). Dark-blue limestone in the bed of the run. It shows a slight dip N. 45° E. Six other drifts are opened on the run, which the limestone, 7½ feet thick, underlies for 300 yards.

At *Snyder's mill*, upon the N. side of the river, are two drifts upon the Pittsburg Coal, at a height of 80 feet above the water. Brown shale extends above it. A short distance below it is the usual thick limestone stratum, here 3 feet thick, remarkably hard and solid, and covering the shore with the fragments of its outcrop. Under it are at least 15 feet of shale. This is 6 miles below Robbstown.

The coal at this point is subdivided into—*Coal*, good, 4 feet ; clay, 1 foot ; coal, 6 feet exposed. (See Fig. 521).

High above two banks, a quarter of a mile farther up the river, heavy strata of sandstone crop out along the hill ; the coal itself is here 70 feet above the water.

A mile farther up, the massive limestone, now 4 feet thick, skirts the water-level, and finally disappears beneath it.

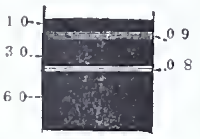


Fig. 520.

At the mouth of Little Sewickly Creek, the Great Limestone (above the Pittsburg Coal forms with its thick strata the hill-side, while the coal-bed lies in the creek.

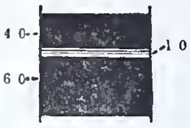


Fig. 521.

On the N. bank of the Big Sewickly the Great Limestone is seen in walls 30 feet high, a stratum of slaty sandstone seemingly dividing it midway at about 50 feet above the creek. The Pittsburg Seam is probably above water-level at the mouth of the Big Sewickly Creek.

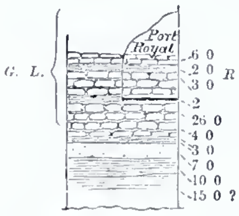


Fig. 522.—Sewickly Creek.

The limestone is again well exposed half a mile farther towards Robbstown, where a rivulet enters the creek. It presents appearances precisely analogous to those that characterise it at Brownsville. A section of it (see Fig. 522), commencing at about half the height of the hill, and descending in the series of its strata, will read as follows:—

Limestone, hard and blue, 6 feet. Shale, blue, 2 feet. Limestone, black, slaty, but with a clean fracture, and effervescing freely, 3 feet. Limestone, light-blue, weathering white, in layers of 2 feet each, two of them of a flaggy structure, 26 feet. Limestone, dark blue, in layers, 4 feet. Clay, or calcareous blue shale, 3 feet. Sandstone, grey, slaty, micaceous, 7 feet. Shale, yellow, brown, and black, 16 feet exposed, but it probably continues down to the water of the creek, and is then 25 feet thick.

At Robbstown (West Newton) the Pittsburg Coal-bed has already sunk below the river-bed of the Youghiogheny.*

From Robbstown to Port-Royal, 4 miles above the former place, the outcrops of the Great Limestone scarp the sides of the valley, forming the major part of the hill-sides, and contain at Port-Royal the *Redstone Coal-bed,* 2 feet thick, of good quality, and lying immediately between two layers of the limestone mass.—(See Fig. 522.)

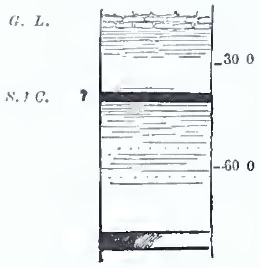


Fig. 523.—West of Robbstown.

At Pollock's mill, 1 mile W. of Robbstown, the *Sewickly* (?) *Coal* occurs, 60 feet above the Pittsburg Bed, 3 feet thick. No limestone is seen between them. The quality of the latter is good, but its thickness is very variable, it thins out locally in some directions.—(See Fig. 523.)

The next coal above is seen 4 feet thick, in a high knoll $2\frac{1}{4}$ miles W. of Robbstown, and near the turnpike. Near the roof is a clay-bed 6 inches thick. It is a brown inferior coal, with 30 feet of hill above it.

The same seam (Uniontown ?) is opened at nearly three-fourths of a mile S.W. of the last locality; and here the Great Limestone is exposed plainly below it.

The Pittsburg Coal is exposed at the mouth of the run which enters the Monongahela, S.W. of the last-named opening, and 2 miles above Williamsport.

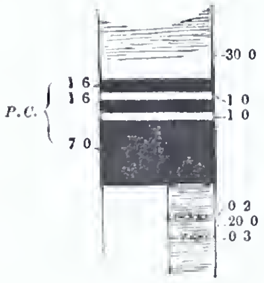


Fig. 524.

For 6 miles above Robbstown the massive fragments of the Great Limestone cover the shores of the Youghiogheny.

The Pittsburg Coal-bed at Port-Royal must be at a considerable depth below the river-bed, since the shales above it form the banks, and the coal emerges at a mill one and a half miles above the town. At an imperfect opening, half a mile above the mill, a clay stratum, 2 inches thick, may be seen traversing a section of the coal 2 feet in thickness, in a diagonal direction. At another opening, half a mile higher up the river, the members of the bed are as follows—(see Fig. 524.):—

Shale, 30 feet; *Coal,* 18 inches; Clay, 1 foot; *Coal,* good quality, 18 inches; Clay, 1 foot; *Coal,* 7 feet exposed.

The bed rises with sufficient rapidity to be 35 or 40 feet above the water, at the two next openings a fourth of a mile higher up the river. Under the coal, shale appears for 20 feet, containing ten small bands of ore; the lower one is nodular.

Half a mile below the mouth of Jacob's Creek, and upon a run which enters the river by the left bank, are openings upon the Pittsburg Coal-bed, exhibiting the two clay interlayers and the lower member, 8 feet thick. Fifteen feet beneath the coal, the limestone appears in the run very black, hard, and in a single massive stratum; beneath it is a grey calcareous sandstone. The coal-bed is again opened at Whitaker's mill.

---

* The first coal-bed struck in boring the salt-well here was at a depth of 280 feet.

Mr Davis's Bank is the first upon the S. side of the river, a little below the mouth of Jacob's Creek, and 25 feet above the water-level.

Above the mouth of Jacob's Creek, on the N.E. side of the river, a small isolated patch of the Pittsburg Coal-seam has been left opposite the shovel-factory.

As the seam rises, when traced up the Youghiogheny River, it has been opened 1 mile above the mouth of Jacob's Creek, and 70 feet above the stream: the roof is slate and sandstone. It appears again in the first ravine from the S.W. above this bank: here the coal strikes the water-level of the stream in the ravine, and disappears at the river, 350 yards from it.

The Pittsburg Coal has been repeatedly opened along the river-shore, still farther up, as it gradually descends to the water-level, being mined only 15 feet above the stream at the shovel-factory, 2 miles below Perryopolis.

Here the bed begins to rise as we continue to ascend the river, and is opened at an elevation of 70 or 80 feet, 500 yards above the factory: the outcrop then turns into a little valley which enters from the S.E., and ascends its left bank.

The hills from hence to Perryopolis are not high enough to contain the bed: they rise abruptly from the river, but do not attain an elevation of more than 150 feet, their summits forming the edge of the so-called flats of Washington. A level of 1000 acres is covered with round water-worn stones, and surrounded by a lofty and denuded country.

The surrounding hills are rounded and low. In this neighbourhood a pure sand is obtained, which is used for making glass both here and at Pittsburg.

Carson's sandbank is about half a mile from the river, on the edge of a sloping hill, and is about 20 feet deep. The general colour of the sand is pale reddish-yellow. Where the sand is pure white, the grains are seen to be soft, fine, and much smaller and cleaner than the yellow grains. The side of the hill is covered with rounded blocks of sandstone, from 12 to 20 inches in diameter. Perfectly-rounded pebbles of sandstone, as large as a man's fist, are imbedded in the sand itself for several feet below the surface. The sandstone of these boulders bears the aspect of the peculiar "salt-rock" of the Chestnut Ridge. Blocks of coarse conglomerate, with white quartz pebbles, are mingled with them, and come from the direction of Laurel Hill or Alleghany Mountain still farther E.

A section of the layers in the sand quarry is as follows:—

> Soil, with sand and pebbles, about 3 feet. Sand, brown, impure, 4 feet. Sand, very white, in regular layers, 9 inches. Sand, brownish-red with black streaks, and quite compact, 4 feet.

It is supposed that the sand results from the decomposition of the extremely friable, loose, "salt-rock" boulders, and the stratification of their disintegrated constituents has occurred in hollows of the surface along the benches of the hill-sides.

Other localities occur between Perryopolis and East Liberty, where the relation between the sand and boulders may be satisfactorily studied. Four miles above Perryopolis, blocks of the salt-rocks are seen upon the surface, 10 feet square by 4 feet thick, lying irregularly in the woods, and sometimes partially decomposed; they are externally of a dark-grey colour, but internally of a yellowish-brown, with red streaks, very friable, coarse-grained, and readily fractured. The edges of the harder parts of a block resisting decomposition are traceable in numerous nearly parallel ridges across its surface. These ridges are of a dark-red colour, and contain more iron than the rest of the mass. The irruption of these blocks certainly dates with the breaches of the Youghiogheny gaps through Chestnut Ridge and Laurel Hill.

Perryopolis.—The coal-openings S.W. of the town are Fuller's and Campbell's, one a mile and a quarter from Perryopolis, and one at G. Stickler's, at the steam-mill, near the water-level, and dipping pretty steeply W.: one mile S. of the last, Mr Power has an opening high upon the hills which border the valley in which is Stickler's mill. Besides these we may notice as opened at the time of our visit, A. Robison's, R. Patterson's, near its W. disappearance below the water-level of the run ; half a mile farther S., Cook's and Wolf's (floor here limestone), Hazen's ; E. Cope's, at the bottom of a deep draught S. of Hazen's ; Fraser's, half a mile from the Redstone, where the hills are high rounded knobs, overtopping the hills upon the first sub-axis, W. of them ; McVey's and Sharpless's, where the outcrop falls into the Redstone valley, low down and near the hill, 3 miles below the Connellsville Turnpike. Here the lower coal-bench is 9 feet thick, 1 foot blue shale ; upper member, coal and slate, 4 feet ; roof, blue slate, 12 feet.

Tracing the outcrop of the Pittsburg Coal-bed in the second subdivision of the third great basin S. from the point where it crosses the Redstone Creek, it dips E. underneath the water, 300 yards below Sharpless's mill : it has been opened by Mr Hornbeck a quarter of a mile above the mill, and by Brown, McCoy, Cowell, Vale, and Seanight, near the National Road. E. of Vale's, and high on the hills, are Mr Wood's openings ; Graham's, and others, near the National Turnpike, as well as at the turnpike E. of the toll-gate, 5 miles from Uniontown.

ROCKS ABOVE THE PITTSBURG COAL, WEST OF THE SECOND SUB-AXIS, AND SOUTH OF THE PITTSBURG AND GREENSBURG TURNPIKE.

The rocks of the upper series, forming the hills along the Big Sewickly Creek, between the two outcrops of the Pittsburg Coal-bed, at the termination of the second sub-axis, are given as accurately as the observations could admit in the section (Fig. 525) as follows :—

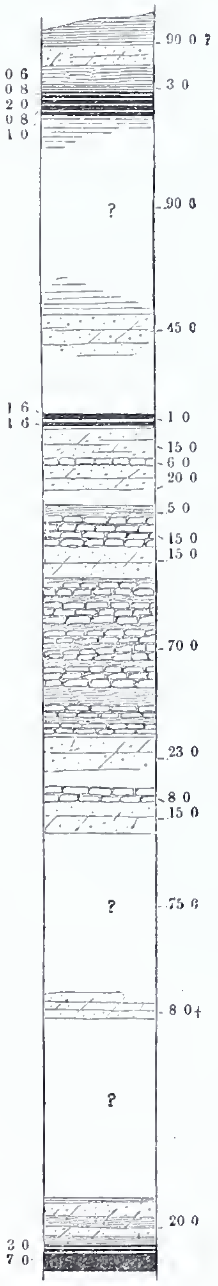


Fig. 525.—Big Sewickly Creek.

Slates and Sandstones in the highest hills, 90 (?) feet. Coal-bed constituted thus : Black Slate, roof, 3 feet ; *Coal,* 6 inches ; Blue Shale, 6 inches ; *Coal,* 8 inches ; Blue Shale, 3 inches ; *Coal,* with thin slaty interlaminæ at every inch, 2 feet ; Blue Slate, 8 inches. *Coal,* 8 inches ; Blue Slate and Coal, 1 foot. Strata not exposed, 90 feet. Coarse grey Sandstone, lower part greatly contorted and filled with wedges of coal, 45 feet. *Coal,* 18 inches ; Slate, with interlaminæ of coal, 12 inches ; *Coal,* 18 inches ; Thin Slate. Grey Sandstone, 15 feet ; *Limestone,* 6 feet. Micaceous Sandstone, flaggy, 20 feet ; Blue Slate, 5 feet. *Limestone,* massive, 15 feet. Coarse grey Sandstone, massive, 15 (?) feet. Limestone, blue, yellowish, whitish, pure or silicious, including thin layers of sandstone and slate ; and 10 feet of dark olive shale, few fossils in any part of the mass, 70 feet. Micaceous sandstone, 23 feet ; *Limestone,* 8 feet. Micaceous Sandstone and olive slate, 15 feet. No exposures, 75 feet ; Sandstone, 8 feet, exposed. No exposures, 85 feet ; Dark olive Slate, 20 feet. Pittsburg Coal, upper member, 3 feet ; lower, 7 feet.

The Sewickly and Redstone coal-beds do not appear in this section ; they probably occur in the lower intervals.

The Great Limestone in the section crops out along the hill-sides from the Presbyterian Church, where it was observed all along the creek as far as Markle's mill, forming steep banks of considerable height, and lying nearly horizontal, only one or two undulations being perceptible.

The whole thickness of the rocks in the upper part of the section obtained above the mill is probably under-estimated, as several exposures could not be so identified as to appear in the section.

The double coal-seam is probably the Uniontown Coal.

The 9-feet bed of mixed coal and slate is found high on the hills S. of Markle's mill, and reminds us of Cox's Coal, occupying a similar stratigraphical position on the highest knob in the first sub-basin S. of the Youghiogheny River. This is the bed, the outcrop of which is seen upon the Robbstown and Mount Pleasant Turnpike.

The Sewickly Coal-bed rises from the water 3 miles below Markle's mill, and the Pittsburg Coal re-emerges 1 mile farther on, the first opening upon it being 1 mile from the mouth of the creek.

Following the upper group of rocks above the Pittsburg Coal-bed, Southward to the valley of the Youghiogheny, below the mouth of Jacob's Creek we see exposures of them, which we have placed in sectional form (Fig. 526).

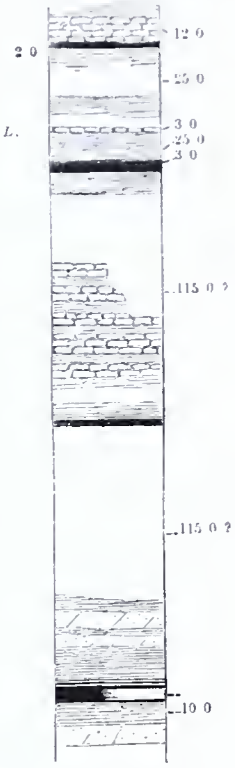


Fig. 526.—Youghiogheny River.

The Pittsburg Seam, opened by Messrs Anderson and Porter, rests upon blue slate 10 feet thick, and this on sandstone. It is overlaid by 40 feet of brown shale, and disappears beneath the water. Five hundred and fifty yards below its disappearance, the Sewickly Coal-bed is seen in an opening. This bed is here 4 feet thick; it yields good coal, and is overlaid by soft brown shale, with sandy layers and blue shale, splintering like old wood when fractured; over this lies sandstone, and over it the Great Limestone strata.

Calculating the vertical distance between the two beds from the distance between the openings, and supposing the uniform dip of the rocks 5°, it will be about 115 feet.

One-fourth of a mile below this opening, and opposite Smith's mill, in the hill-side S. of the river, we find material for continuing the section upwards, thus:—

> Blue Shale at the water-level. *Coal*, deep-black, hard, shining, at the water-level, $3\frac{1}{2}$ feet; Roof, black Slate, 3 feet; Slate, 12 feet, blue, including a limestone stratum, 3 feet thick; Sandstone, 10 feet; Yellow and olive Shale, 25 feet; *Coal*, 2 feet; Limestone roof, impure, yellowish, massive, 12 feet.

At Williamsport (Monongahela City) several drifts are opened upon the Pittsburg Coal, exhibiting in all the same relationship existing between its members, viz.:—

> Soft yellow Shale, 6 feet; *Coal*, impure, 3 feet; Clay, 1 foot; *Coal* (lower member), 6 feet; Limestone, top visible.—(See Fig. 527.)

Ten feet under the coal is seen the top of a brown shale stratum, 20 feet thick, full of ferruginous concretions. Pursuing the course of the Pigeon Creek upwards from the town of Williamsport, a stratum of sandstone, 10 feet thick, is observed in many places capping the hills on each side: it is separated from the Pittsburg Coal by the capping of shales which overlie the latter, and it may be considered the representative of the Pittsburg Sandstone.

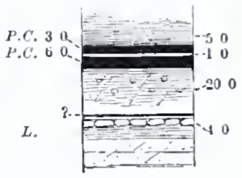


Fig. 527.—Williamsport.

At the mill-dam, $1\frac{1}{4}$ miles above the town, the limestone under the Pittsburg Coal forms a broad checkered pavement for the creek, and a little above this the coal itself forms the bed of the stream. Above this, shales and sandstones occupy 30 feet.

At Williamsport, the hills to the W. form a flat table-land, covered by the Pittsburg Sandstone; those to the E. are greatly more elevated, rising 300 feet steeply from the river; but they afford no natural sections. At their base runs the outcrop of the Pittsburg Coal and underlying limestone.

A quarry of sandstone, covered with shale, occurs above the roadside; and two-thirds of the distance up the hill, 30 feet thickness of it is exposed.

Two miles from Williamsport, on the Brownsville State Road, the Great Limestone appears in the stream, from 30 to 35 feet thick, and in 6 or 8 layers, overlaid by slaty grey sandstone, upon which are several additional layers of limestone. Where the State Road crosses the Turnpike Run, above Greenfield, the Pittsburg Coal is opened; it is thus subdivided:—

> Lower member, *Coal*, 7 feet; Clay, 1 foot; Upper member, *Coal*, 1 foot; Black Slate, 3 feet.

From this bed, which is here 30 feet above the water, great quantities of coal have been extracted farther up the run. Between Morris's banks and Fredericktown the Pittsburg Coal-bed has the Pittsburg Sandstone immediately resting upon it; a fact which we may ascribe to an ancient slide hiding the outcrop of the intermediate shales, which may be explained by an imaginary section, as in Fig. 528. (*A b* represents the soil on the face of the hill, *c* the shale, the outcrop of which is covered by the slide of the sandstone above.) The hills are very steep, and remains of such slides are visible. At Fredericktown the Pittsburg Coal is at least 50 feet above the river.

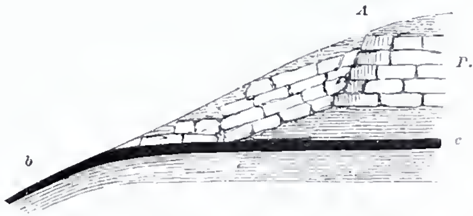


Fig. 528.

Between the quarries below Belvernon and Columbia, the Pittsburg Coal lies high upon the hill-sides, overlooking the Monongahela Valley. At two drifts, 2 miles below Columbia, the bed is opened 140 feet above the water-level. Beneath the coal a sandstone stratum, 10 feet thick, is seen. A limestone stratum is seen above the coal, and another below it, at an opening up a run which enters the river at this point.

Half a mile below Cookstown, the Pittsburg Coal is opened at an elevation of from 100 to 120 feet.

Half a mile below Belvernon, on the W. side of the river, is the sandstone quarry (Pittsburg Sandstone ?) which furnished the stone for the Williamsport Bridge. It is a hard, compact, tough material. Some layers of it contain ferruginous concretions, which injure its appearance, and increase the difficulty of working it as a building-stone. The colour is light-yellow and grey. The main breast is a stratum 18 feet in thickness, containing carbonaceous impressions on the surface.

Upon the sandstone is a mass of compact slates, 20 feet thick, seemingly once subjected to great pressure from above, and filling the chasms and interstices of the sandstone mass beneath it; the line of juncture between these two formations is extremely irregular. In one instance observed, the inserted rock was a mixture of ferruginous clay, slate, and impure coal. The same appearances are observed in the quarries at Williamsport.—(See woodcuts *a* and *b*, Fig. 529.)

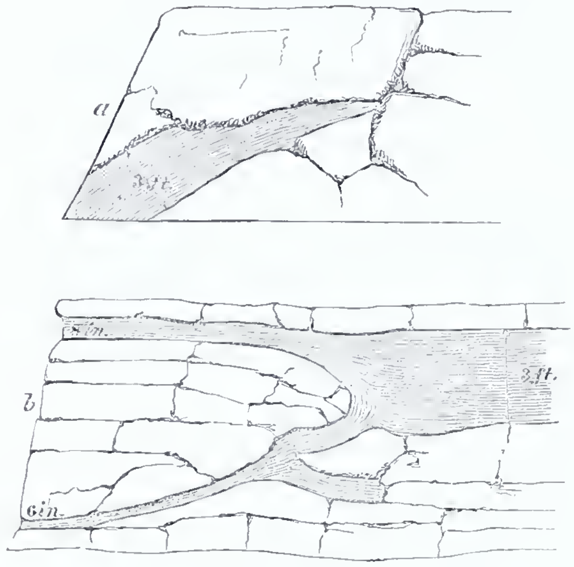

a
3 ft.
8 in.
b
3 ft.
6 in.

FIG. 529.

At the town of Greenfield, and below it, are numerous drifts in the Pittsburg Coal, the variable types of which will be comparable from the accompanying vertical sections. At the first drift (Fig. 531) the coal is about 25 feet above the run; at the second (Fig. 530), the limestone underneath it is 10 feet thick, and divided by layers of soft black shale. Here some layers of iron ore, 3 inches thick, occur in the bed of the run. The limestone is water-worn, and reddish on the surface, yields readily to the knife, and is full of vegetable remains, as are also the slaty layers.

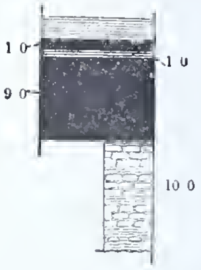


FIG. 530.—Pike Run.

The fourth drift is at the steam-mill.

At the second drift upon the river below the town, a sandstone 18 inches thick rests immediately upon the upper members. The bed is about 50 feet above the water.

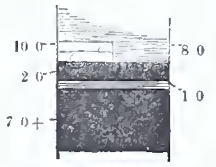


FIG. 531.—Below Greenfield.

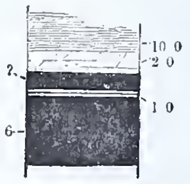


FIG. 532.—Below Greenfield.

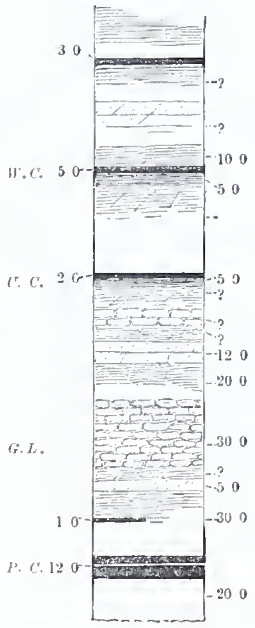


FIG. 533.—Brownsville.

Two miles below Brownsville, a coal-bed is seen on the Greenfield Road, on the top of a high hill. Assuming Brownsville as a centre of observation for the surrounding country, where investigations are not readily reduced to accuracy through continuous vertical sections, we offer the following as a *typical section*, based upon examinations first made here, but afterward extended up and down the river and its numerous side-waters. The section is exhibited in Fig. 533 :—

Yellow Shale. *Coal*, 3 feet. Yellow Shale, coarse brown sandstone. Shale, blue, yellow, sometimes wanting, 10 feet. *Coal*, 5 feet (Waynesburg Coal). Yellow Shale (upper part clay) with concretions, 5 feet; Black and yellow Shale, 40 (?) feet. *Coal*, 2½ feet (Uniontown ? Coal). Soft yellow Shale, 5 feet; black and yellow Shale, with sandstone layers. *Limestone*, upper layers black and slaty, separated by shale. Slate generally brown, friable, and fossiliferous; paving sandstone, fine-grained, excellent building-material, micaceous on the surface, compact or slaty, lower part generally compact, abounding in vegetable impressions, 12 feet; Yellow and black Shale, 20 feet. Limestone, hard surface, white, blue within, interlaid by Shales, blocks crumbling on exposure, sometimes scaling off with conchoidal fracture; upper portion blackish and more slaty, exhibited on National Road, at Kreb's Hill, Mouth of Redstone, Muddy Creek, &c., forming high white precipitous cliffs, 30 feet. (*Great Limestone.*) Shale, brown and yellow, thin ; Sandstone (Pittsburg Sandstone), compact, here only 5 feet ; Shale (sometimes absent), brown, with layers of sandstone (increasing in number upwards), contains on Redstone a thin coal-bed (Redstone Coal), 30 feet. *Pittsburg Coal*, two members, and clay between, 12 feet thick.

Opposite Brownsville, a high sharp hill called Kreb's Knob, overlooking the surrounding country, and visible from a great distance, exhibits the following section—(see Fig. 534) :—

No exposures except a few thin layers of Limestone, and a thin coal outcrop, 50 feet. These are near the summit, but above them are visible at one place 20 feet of Sandstone, and a coal-bed evidently thin. No exposures, but fragments of Limestone, 35 feet. Micaceous Sandstone, with coal laminæ at its bottom, 40 feet ; Blue Shale, 2 feet. *Coal*, 1 foot ; Blue Slate, 4 to 8 inches. *Coal*, 15 inches. No exposures, 65 feet. Micaceous Sandstone, 7 feet ; No exposures, but fragments of Lime and Sandstone, 23 feet ; Blue Shale and sandstone, 10 feet. Great Limestone of different colours, alternating with blue shale, 30 feet ; Dark olive Slate and sandstone layers, 28 feet. Limestone, yellow, impure, at water-level, below which but a small distance must lie the Pittsburg Coal-bed.

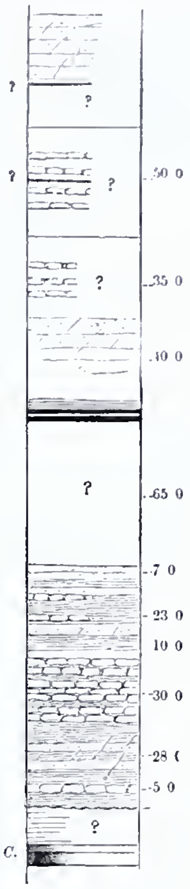


FIG. 534.—Kreb's Knob, at Brownsville.

On the road to the E. of Brownsville, the following section (Fig. 535) was compiled :—

Brown and black Slate from 8 to 20 feet ; the Great *Limestone ?* fine-grained, with layers of light-blue shale, disintegrating upon exposures, from 25 to 40 feet ; Yellow Shale.

Above these occurs a limestone bed, 4 feet exposed ; and near the summits of the hills, 150 feet higher, the following descending series of rocks :—

Coarse brown Sandstone, 25 feet ; Blue and yellow Shale, 5 feet ; *Coal*, 5 feet ; Shale, 5 feet, &c.

This is a valuable bed of coal. The sandstone is exposed in three separate quarries along the turnpike, and forms the summits of the hills. It is coarsely compacted of water-worn grains of quartz of the size of small shot. Its larger layers have their grains united by no cement, and therefore exposure rapidly crumbles it down into a coarse sharp-grained white sand. The strata are much disturbed and broken, though maintaining their general horizontality. Upon the run, below the Great Limestone, the following rocks were discovered :—

Sandstone, 20 (?) feet ; *Black Limestone*, with interposed Shales, 20 (?) feet ; Sandstone, 20 (?) feet ; Yellow and black Slate, 8 feet ; *Coal*, 1 foot ; Black Slate, 35 (?) feet ; *Pittsburg Coal*.

Here the Pittsburg Coal shows two members thus :—

Black laminated Slate, 17 feet ; highly carbonaceous pyritous Slate (upper member), 2 feet ; Clay, 1 foot ; *Coal* (lower member), 7 feet.

This slaty upper member will burn when mixed with the lower coal, and moistened. The nodules of sulphuret of iron, when broken, exhibit vegetable impressions. The limestone beneath the Pittsburg Coal is separated by horizontal planes of clay and black slate ; it is sometimes slaty, sometimes compact, and emits a strong bituminous odour when freshly broken. It is 10 feet thick at one drift ; at another drift it has beneath it—

Black laminated Shale, 2 feet ; *Coal*, 1 foot ; Limestone, 15 inches ; Soft blue Shale, full of calcareous nodules, 6 feet in the bed of the run.

The Great Limestone is again exposed a mile higher up the run. In one quarry, on the brow of the hill, behind the Cove, the Pittsburg Sandstone is seen to contain abundance of Calamites and vegetable impressions in the solid layers.

The Pittsburg Seam is opened at Cox's and Mitchell's banks. At the mouth of the former drift the clay band is not visible ; in the other, it is 2 feet thick.—(See Figs. 536, 537.)

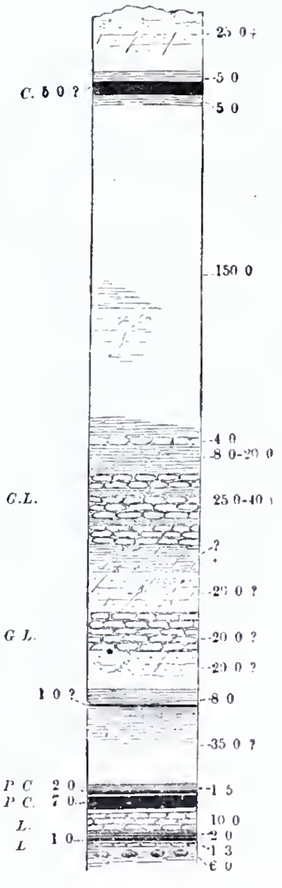


FIG. 535. — East of Brownsville.

In Fig. 538 we have a section of the rocks above the Pittsburg Coal, as exposed along Redstone Creek between Sharpless's mill and its point of emergence near Linn's mill, thus—

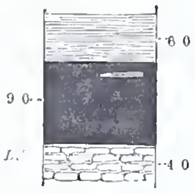


Fig. 536.—Cox's Drift.

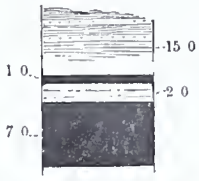


Fig. 537.—Mitchell's Drift.

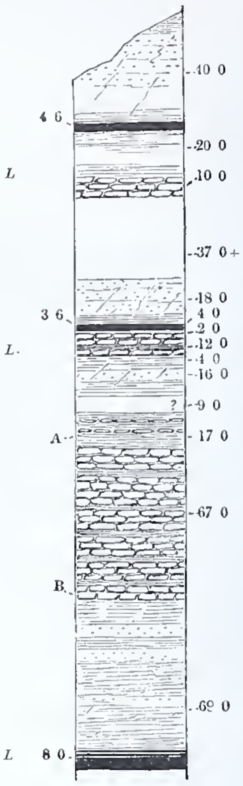


Fig. 538.—Redstone Creek.

Slate and Sandstone, thickness unknown ; Coarse grey Sandstone, massive, 40 feet. *Coal*, with Slate seam, from 6 to 8 inches thick, 1½ feet ; from the roof, 4 to 4½ feet. A few exposures of slate, &c., 20 feet. Limestone, yellow and blue, impure, with slate bands, 10 feet. No exposures, 37 feet ; Micaceous Sandstone, blue and grey, 18 feet ; Yellowish and bluish Shale, 4 feet. *Coal*, soft brown, crumbling, from 3 to 4 feet ; Floor, black Shale, 2 feet ; Limestone, blue and ash-coloured, 12 feet ; Calcareous yellow Shale, 4 feet ; Yellow Shale, with grey Sandstone, 16 feet. Not exposed, 9 feet ; Slate, with calcareous layers, 17 feet. Great Limestone, strata of different colours, and interlaid with slates and shales, 67 feet. Dark olive and brownish Shales, and slates with layers stained with the rust, and containing occasional nodules of carbonate of iron. Pittsburg Coal, 8 feet.

From A upward the rocks were measured in a gorge near Redstone paper-mill, about 3½ miles from the mouth of the creek, and from B downwards, near Linn's mill. Though the parts were measured, some error may exist in the manner of their connection in the section. The section at Brownsville, however, confirms the general view as correct.

The Great Limestone is often exposed along the creek.

Upon the road leading Northward from the National Road, 5½ miles E. of Brownsville, lie great masses of a ponderous sandstone stratum scattered over the surface.

About 3 miles from the turnpike, the Pittsburg Coal-bed is wrought at the bottom of a run, it is roofed with black slate, and sandstone is exposed for 15 feet above.

Beneath the coal is seen a limestone bed in several layers, 10 feet thick ; one of the layers contains nodules of iron ore. Blue slate underlies the limestone, and passes downwards into sandstone, which occupies the run thence to the Redstone Creek. The lower part of the shale is full of calcareous concretions, from 1 to 12 inches in diameter.

The Pittsburg Coal at this locality is about 40 feet above the level of the creek, and rises Westward obedient to the first sub-axis.

Higher up the run the *Great Limestone* is seen.

UPON THE ROAD FROM BROWNSVILLE TO UNIONTOWN.

The *Five-Feet Coal* (Waynesburg [?] Coal) can be traced along the National Road a distance of 4 miles from Brownsville eastward to its Eastern outcrop.

The *Two-and-a-Half Feet Coal* (Uniontown [?] Coal) crops out upon the National Road 5½ miles E. of Brownsville ; and the Pittsburg Coal-seam, 7½ miles E. of Brownsville, and 4¼ from Uniontown. Its Eastern outcrop has already been traced by the line of openings upon it. Here the coal dips at an angle of 2° W. The Westerly dip continues evident to within 2 miles of Brownsville.

Upon the road leading S. from the first milestone E. of Brownsville, the sandstone above the Waynesburg (?) Coal-bed appears in large blocks strewed about ; it is of a coarse and friable texture. Farther S. is seen the outcrop of a higher coal, at least 3 feet thick. The Five-Feet (Waynesburg [?] Coal) appears on the hill-side 60 feet below it ; roof, yellow shale (covered by gravel and pebbles of sandstone, and then the soil), 3 feet ; *Coal*, 2½ feet ; Clay, 7 inches ; *Coal*, good, 6½ feet exposed—perhaps thicker.

The sandstone above mentioned, in very large blocks, is again apparent half a mile S. of the coal drifts, with again a trace of the Waynesburg (?) Coal below it.

Descending the hill-side to Duncan's (Dunlop's) Creek, the following rocks appear, in all perhaps 100 feet in thickness. Sandstone, slaty, 6 feet. Interval. *Limestone*, first in the layers, with shale interlaminations; lower part in four layers, 10 feet thick. Sandstone of considerable thickness; brown shale, 6 feet; very black soft shale, 4 feet. Limestone descending to the creek's bed, slates in the upper portion, 10 feet exposed. This limestone-bed is seen several times in the creek, where the road descends to it a second time, 3½ miles from Brownsville; and again at the mouth of the run, a fourth of a mile farther, at Merritstown, where it presents this section, dipping in the direction E. 10° N. Sandstone, limestone, sandstone and shale, some of the layers effervescing with acids; limestone, hard, semi-crystalline, with spots of pure spar: altogether perhaps 35 feet. The limestone forms the creek-bed above the town. Two miles N.E. of Merritstown the small Uniontown (?) Coal appears at half the height of the hill; floor apparently 10 feet of shale.

At *New Salem* are many openings in the Pittsburg Coal and other seams. The former coal is here 8 feet thick.

One and a half miles due N. of *McClellandtown*, on the side of a high hill, the Uniontown Coal-seam is exposed, 2½ feet thick. The hills are here high, and are no doubt based almost immediately upon the Pittsburg Coal.

The Uniontown Coal is again seen, 2 feet thick on the road, 5½ miles S. of McClellandtown. Some distance below it is the Great Limestone, and above it yellow shales compose the hill, which is itself one of a remarkable chain of conical eminences ranging N. and S.

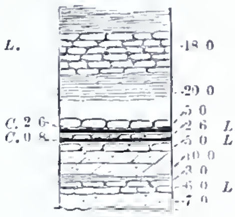


FIG. 539.—Brown's Run.

Half a mile from this point, at the mills upon Brown's Run, and perhaps 150 feet in depth, from the steep banks of the run, the following tolerably accurate section (see Fig. 539) was obtained:—

At the top of the section, *Limestone*, hard, splintery, deep blue, speckled with crystalline sparry limestone, estimated at 18 feet. Blue Shale, lower portion a black slate, with calcareo-ferruginous concretions seen on both sides the creek, 20 feet. *Limestone*, upper part slaty and black; lower part massive, interlaid by calcareous shales, 5 feet. *Uniontown Coal*, 2½ feet; Floor, black Shale, 3 inches. The limestone rests directly upon the coal, the upper 6 inches of which are true bony coal, that is, fine interlaminations of coal and slate. The bed seems to have been much compressed, and breaks out in cubes measuring 2 feet on a side. The lower few inches are not good. *Limestone*, single, hard stratum, 2½ feet. *Coal*, 8 inches. Pure Coal, with a little black slate above and below it about 1 inch. A large part of the bed is pure glassy coal; other parts of it are interleaved coal and slate. Blue friable Shale, thin. *Limestone*, hard, blue, with thin shale interlayers, 5 feet; Thin Shale, 1 foot. Paving Sandstone (of the Brownsville section), distinguished by its peculiar stratification, in bands only an inch or a few inches thick, while blocks of it appear which are 10 feet long, 4 broad, and 4 thick, and lie upon the hill-side. These might be split into flags, as a closed book separates into leaves. The upper layer is here 1 foot thick; then commences the slaty or flaggy portions, 10 feet. Shale, lower part bituminous, 3 feet. Limestone, hard, blue, non-fossiliferous, 6 feet. Sandstone, base of the hill and bed of the run, massive, grey, fine-grained, rather slaty in parts, 7 feet exposed.

At Germantown there are numerous openings in the Pittsburg Seam. For two miles of its course from the river, Cat Run exposes this bed; its thickness is 8½ feet; the clay stratum is 1 foot thick, and near the top the floor of the coal is limestone. Sandstone, light grey, fine-grained, 20 feet; above this, friable slate, containing vegetable impressions, 10 feet: Calamites and other vegetable impressions occur in the solid sandstone. The Pittsburg Sandstone may be traced for 1½ miles below the town, down the W. bank of the river, the latter forming ledges of rock.

No exposures are visible along the W. side of the river in ascending from Brownsville to Crawford's Ferry, 3 miles.

Numerous coal-openings occur within 3 miles of Fredericktown. At Verron's the Pittsburg Coal-bed is 7 feet thick; roof, clay, 1 foot; coal, 18 inches: Pittsburg Sandstone, massive, 30 feet thick. The dip of the bed is said to be due N., or down the river, and its elevation above water-level 25 feet.

Nineteen coal-drifts may here be counted along the outcrop of the Pittsburg Coal. In all, the Pittsburg sandstone is seen resting upon the 18-inch upper member of the Pittsburg Coal, fine-grained and compact, at least 30 feet thick, and overlaid by pyritous brown shale, perhaps 18 feet thick, and this again by 3 feet of sandstone.

In some places the sandstone is much water-worn, as if it had once been subjected to the action of the river-currents standing at a level higher than the present.

At Crawford's Ferry, 2½ miles above Brownsville, the Pittsburg Coal lies in the river-bed; the men employed in mining it are compelled to stand in water up to their knees. Its coal is of the best quality, burning freely, and breaking out of the bed in large masses, some of them 3 feet in length. This quality of the coal mined in running water has been already alluded to, in speaking of a coal-bed in the first sub-basin. The bed has been quarried in this manner a mile along the river bottom for more than twenty years.

One mile above Brownsville a stream comes in from the W. side, upon which the following section was obtained:—

Slaty Sandstone, soft black slate, 5 feet; Black calcareous Slate, 3 feet; *Great Limestone*, 40 feet; Black Slate, 5 feet; Slaty Sandstone, 18 feet; Black Slate, 8 feet; Slaty *Limestone*, 6 feet; Hard blue *Limestone*, 10 feet.—(See Fig. 540.)

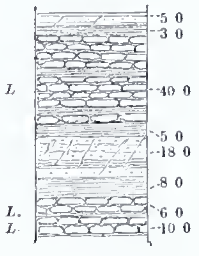


FIG. 540.—One mile above Brownsville.

It is possible that the lower limestone may be a slide upon the hill-side from the upper limestone.

At the mouth of Ten-mile Creek both the Pittsburg Coal and Pittsburg Sandstone are exposed; the latter probably lies near the surface all the way S. to Carmichaeltown, where it is again exposed.

Two and a half miles S.W. of Carmichaeltown, and 1½ miles from the river, the Sewickly (?) Coal, which is occasionally seen to the N. of that place, is wrought at Ingram's Tavern, and yields a good coal. The section (Fig. 541) is as follows:—

Soil, 3 feet; Broken Sandstone, 3 feet; Yellow Shale, 2 feet; *Coal*, tolerably good, 3 feet; Clay Slate, 6 inches; *Coal*, 3 feet. Floor, clay filled with nodules of carbonate of iron (?)

Half a mile farther up the creek, the strata of limestone, 12 feet exposed, lie in the bed of the creek, capped by yellow shales, which underlie the coal-bed, how far is not known.

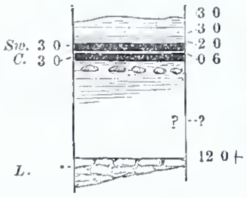


FIG. 541.—Two miles and a half W. of Carmichael.

The coal-bed, at least 4 feet thick, is again seen upon a brook, which enters the creek half a mile farther up. Beyond this point is seen descending from the brow of the hill a tolerably thick bed of limestone; shale and slaty sandstone form a ledge 12 feet thick, then a thick bed of limestone to the creek.

In the neighbourhood of Carmichaeltown there are to the E. three beds of coal.

Upon *Muddy Creek*, three-fourths of a mile from town, the following section was obtained:—

Slaty Pittsburg Sandstone, 32 feet; Friable yellow Shale, 12 feet, apparently much compressed. *Coal*, 3 feet; Clay, 3 inches; *Coal*, 3 feet; Interval, yellow Shale, 40 (?) feet; *Coal*, 2 + feet, 50 feet above the creek.

The coal-bed is wrought for several hundred yards in the bed of the creek, and yields large masses of coal. The dividing-clay is sometimes 6 inches thick, at others it dwindles to an almost imperceptible laminæ of slate.

The Pittsburg Sandstone is beautifully pitted with a thousand holes of every shape. It is compact, and would make a good building-stone.

Under the coal is a bed of shale, 20 feet thick, which contains large quantities of argillaceous iron-ore in flattened irregular nodules as large as a man's fist.

Below the ferriferous shale a limestone-bed is finely exposed in several layers for a mile along the creek, and in the bottom of the shale is a very thin coal-seam.

Sixty or seventy feet above the Pittsburg Coal is another coal-seam imbedded in soft shales, and from 2 to 3 feet thick. At Mr Davidson's bank, this coal-bed (if indeed it is the same) is much thicker.

At the sawmill, lower down the stream, and in the bed of the creek, are shales 12 feet thick, covered by a limestone 15 inches thick. Limestone, perhaps the same stratum, continues for a mile down the stream, covered by shales. At one place, a bed of hard black slate rests upon the limestone in the bed of the creek; this limestone seems here almost like a breccia and might make a handsome marble. The pebbles are of the size of a pea.

Below the last-mentioned locality, a bed of limestone, 20 feet thick, forms the banks of the stream for half a mile, and at last rears two walls from 30 to 40 feet in height, facing each other. This mass of limestone is divided by occasional layers of blue shale. The whole must underlie the double coal-bed before described; and if this be the Great Limestone above the Pittsburg Coal, the seam above it must be the Waynesburg Coal.—(See Fig. 542; observe also the double coal-seam in the Kreb's Knob section opposite Brownsville.)

When traced still farther down the creek, half a mile or so, the limestone is seen to be supported by sandstone, 10 feet thick; this again by shales 20 feet thick. The shale is dark-blue, hard, laminated, splintery, chopping off like woody fibre; it contains a few round nodules of ore, and presents some slight indications of coal.

This brings us to a point on Muddy Creek within 300 yards of its mouth. The Pittsburg Coal-bed must here be far below water-level.

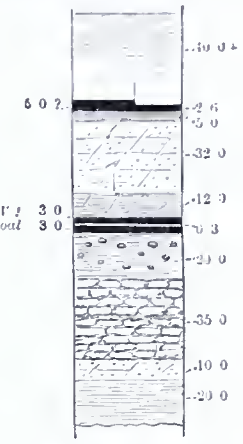


Fig. 542.—Muddy Creek.

Upon a run, 2 miles S. of the Muddy Run mouth, and half a mile from the river, are several drifts upon the same coal-bed, divided, as before, into two beds (upper bench, 2 feet 9 inches; lower, 2½ feet), by 1 foot of clay. These drifts, being 30 feet above the bed of the run, are at a still greater elevation above the river.

At the mouth of the Little Whiteley Creek, both the coal and the limestone (20 feet thick) are exposed.

Opposite New Geneva, in the hill back of Greensburg village, the (Pittsburg?) Coal is mined, and a small bed, perhaps 2 feet thick (Redstone Coal), is seen above it. The latter is underlaid by a stratum of sandstone, 3 feet thick, between which and the lower bed are yellow and black shales.

The flat lands, stretching for 2 miles back of the village, are very fertile.

On Whiteley Creek, at Thompson's mills, limestone, 6 feet thick in the creek, supports a bed of coal, 4 feet thick. The limestone is very hard and black inside; but outside it is of a ferruginous brown, and lies in six layers (see Fig. 543). A section of the whole hillside behind the mill, including the above, is as follows:—

Yellow Shale; *Coal*, thin; Shale and sandstone; *Coal*, Shale; Soft yellow Shale, with sandstone. *Limestone*, thick; Shale; *Limestone;* Sandstone; Limestone in five layers; Sandstone and Shale; Shale, 6 feet. *Coal*, 4 feet; Sandstone, 15 inches; Shale, 15 feet. Limestone in the creek, 6 feet exposed.

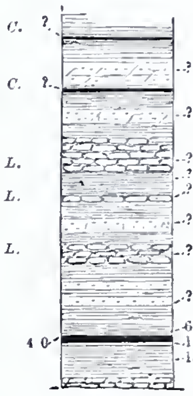


Fig. 543.—Whiteley Creek.

The coal-bed, 4 feet thick, is the same that is worked at Ingram's Tavern, and elsewhere in the neighbourhood, appearing upon the road half a mile S. of Ingram's.

No exposures occur on the flat land within 3 miles of Carmichaeltown to the S.; but the knolls are composed of soft yellow shales, with sandstone strata occasionally interspersed.

At New Geneva the hills are about 300 feet in height, and the Pittsburg Coal-bed is opened within 50 feet of their summit, at the Glass Company's drifts. A section of the strata is presented by the quarry on the hill at the mouth of the creek, which, when continued down to water-level, is as follows:—

First drift, Soil, 2 feet; Sandstone and Shale, with thin coal-seams, 12 feet; *Coal*, solid, 6 feet exposed; floor not known. Second drift, Soil, 1 foot; Broken Sandstone, 5 feet; Shale, soft, friable, 3 feet; *Coal*, solid, 8 feet; floor unknown. Shale and Sandstone, 30 (?) feet; Shale, soft, rotten, laminated, yellow, 15 feet. Quarry: Sandstone, compact fine-grained, light-grey, speckled brown—an excellent building-stone—12 feet. Blue Slate, 5 feet; Sandstone layer, 6 feet; Blue Slate, 10 feet. *Limestone*, 2 feet; Shale, 5 feet. *Limestone*, 2½ feet; Shale, 12 feet. *Limestone*, 2 feet; Shale, 3 feet. *Limestone*, 3 feet; Soft Shale, 3 feet. Sandstone and Shale, 10 feet; to Creek-bed, unknown, 20 feet.

The strata of limestone are light yellow, excessively hard, making a dark lime difficult to burn. The intermediate shales are dark, sometimes black, sometimes decomposing into a soft blue clay, and full of calcareous concretions.

Between George Creek and the river, the country is level, denuded of the coal-bed, and covered with fragments of a conglomerate containing white quartz pebbles.

At the sawmill upon George Creek, a fourth of a mile above its mouth, the sandstone quarried in the above section is again seen, with the same limestone-beds below it, containing transparent specks of spar, and is here chiefly of a buff colour. Some bands of the sandstone are imperfect, conglomeritic, containing pebbles of white quartz as large as a pea. The section here is as follows :—

Soil, Shale, 10 feet ; Sandstone, massive ; Blue Shale, 11 feet ; Limestone, 2 feet ; Shale ; Limestone, 4 feet ; Blue Slate, 7 feet ; Yellow Shale, 10 feet ; Limestone, 2 feet. Interval, Limestone (?) feet ; Yellow Shale, with purple spots, 20 feet ; Sandstone and black Slate on the bed of the creek, 6 feet.

Below New Geneva, a grey slaty sandstone occupies the bed of the river, while its shore is strewn with blocks of limestone dislodged from the outcrops, which are upon the hills above. These are excessively hard and heavy, of a black colour within, but turning brown upon the surface by the oxidation of the iron they contain.

At the first run, 1½ miles below New Geneva, a limestone stratum, 10 feet thick, rests upon the sandstone of the river-bed ; it is massive, hard, and heavy. Upon it rest blue laminated slates, 10 feet thick, passing upwards into slaty sandstone.

A few hundred yards up the run is seen a coal-bed, 1 foot thick ; floor, slaty sandstone in the run ; roof yellow shale, 12 feet, passing upward into sandstone layers, followed by shale, and all capped by 2½ feet of limestone stratum at the summit of the hill-side. This latter limestone is doubtless one of those given in the section (Fig. 543).

Returning N. into Washington County, and ascending Mingo Creek, below Monongahela City, we find an opening a fourth of a mile from the river in the Pittsburg Coal-bed, which seam disappears beneath the creek-level at a point three-fourths of a mile farther up the creek.

Two miles W. of the last locality, and upon the N. fork of the Mingo Creek, a small coal-bed (Redstone Coal) passes also into the bed of the creek. This is no doubt the same small bed that is seen above the Pittsburg Coal, at Robbstown ; it is here about 40 feet above that seam ; is between 2 and 3 feet thick, and nearly horizontal.—(See Fig. 544).

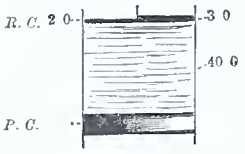


FIG. 544.—Mingo Creek.

The road from Brownsville to Pittsburg ascends the Little Mingo Creek, and gives exposures that are worthy of attentive examination. The Pittsburg Coal-bed is here seen opened at the steam-mill, and may thence be traced N. through Findlaysville, as it gradually and regularly rises to the elevation which it has assumed upon the Monongahela Cliffs opposite to Pittsburg City. The Great Limestone is thus also seen to spread to a considerable distance N. of the National Road, enclosing within its convex outcrop the major part of Greene and Washington counties. Three miles from Pittsburg, on the turnpike to Washington, a quarry has been opened upon a limestone-band above the Pittsburg Coal.

There is an opening upon the Pittsburg Coal-bed one mile W. of Cannonsburg on the turnpike, and another up the valley of the N. branch of the Chartier Creek, distant one mile due West of the first locality ; the plane of the bed has risen (Westward) by measurement about 40 feet.

One mile W. 15° S. of the last, it is again opened nearly at the same level.

Half a mile due West of the last opening, the coal disappears beneath the bed of the creek.

Where the creek comes to a head, and forks as two small rivulets, the soil from the Great Limestone composes most of the hill-sides as they gently slope outwards towards the general elevation of the country, which probably in no place is more than 200 feet above the water at this head of the creek.

Large blocks of coarse sandstone are seen upon the ridge or high lands separating the head-waters of Chartier and Cross creeks.

North of West Middleton, the shales above the Pittsburg Coal abound. Upon Cross Creek, 3 miles to the N. of the town, the Great Limestone is exposed in its lower members about 20 feet above the water-level ; the hills around being little less than 200 feet in height, but gently sloping, and of irregular form.

Descending Cross Creek, the Pittsburg Coal-bed soon appears under the following subdivisions :—

Coal, 2 feet ; Clay, 2½ feet ; *Coal*, 4½ feet.

Near Plumer's mill, one and a half miles farther down the creek, the Pittsburg Coal is wrought at an elevation of 100 feet above the water. Beneath it are seen limestone and very massive sandstone strata.

It is opened again one and a half miles W. of the last; the hills rising 200 feet above the plane of the bed. This is half a mile E. of the Virginia State line.

At the mouth of Buffalo Creek, on the banks of the Ohio, the coal-bed is opened, the hills rising above it 80 feet or more.

The Great Limestone strata are traceable the whole distance from Washington to Wheeling. For 18 miles W. of the former place, along the National Road, the country is very hilly.

At a point 4 miles W. of Washington, several quarries are opened in the Great Limestone. Some of its strata are of a very dark colour, approaching black, which recalls the fact of the presence of the Sewickly Coal-bed, at certain localities, in the very middle plane of the calcareous mass.

Behind the town of Wheeling, at the first milestone, upon the hill-side, the same strata appear very compact, and 30 feet in thickness. The successive layers are parted by calcareous shales.

Ascending Wheeling Creek, the Pittsburg Coal first strikes the bed of the stream, and afterwards the Great Limestone does the same, exhibiting the *Sewickly Coal* within it 2 *feet thick*, at a place a short distance W. of Fridelphia.

At West Alexandria the inhabitants have command of the Waynesburg Coal-bed, but prefer to use the coal from Mr Groding's opening upon the Pittsburg Coal, 7 miles from Wheeling.

Throughout all this country, it will be found correct to say that a great bed of alternating sandstones and shales overlies the Great Limestone: it contains two coal-beds.

From Washington to Waynesburg, upon the National Turnpike near Washington, the Great Limestone is opened in a quarry.

Three-fourths of a mile S. of Martin's Tavern, where the Waynesburg Road leaves the National Turnpike, two sandstone strata are visible 20 feet asunder; the lower one is 5 feet thick, the upper 7 feet; they evidently overlie the Great Limestone, and may be the equivalent of the "Paving-stone" of the Brownsville section. The upper stratum is a compact mass of a greenish-yellow colour, and is homogeneous, fine-grained, and apparently contains numerous minute scales of mica. Part of it breaks into handsome slabs 3 inches in thickness. It lies about 40 feet below the general surface of the country in this neighbourhood.

The Great Limestone is exposed in the hollow, three-fourths of a mile S. of the above locality. Four feet of its upper portion are exposed, and over this lies shale, brown and friable, 20 feet; then sandstone, 5 feet, which may be the lower of the two layers above described: above it there are indications of a coal-seam.

As the bed continues S., these rocks repeatedly expose themselves to the day. At a distance of 1½ miles the road leaves the hollow and ascends a hill, over the sides of which are strewn blocks of coarse brown sandstone, and at its top the stratum appears in place. At the very summit, a hard blue limestone, with a coping of soft yellow shale, is seen. From thence to Amity similar appearances present themselves, but all exposures upon a broad water-shed like this are unsatisfactory, and lead to few results.

The nearest important coal-banks are 4 miles distant from Amity, upon Ten-mile Creek. Three-quarters of a mile S. of Amity, where the road to Waynesburg descends a second time to the creek, is a coal-bed 3 feet thick, with floor of shales and slaty sandstone, 10 feet down to the creek's bed. Large blocks of limestone, 18 inches thick, lie strewn about, having fallen from above. The coal is so poor, being divided by numerous slate-bands, that it is not worth working. The limestone begins to appear about 10 feet above the coal, and seems to be a thick mass when traced up the run. Much shale lies between its layers.

Three miles from Amity the same limestone is seen twice upon a run rising 100 feet above its plane: the hills offer no exposures.

The country from hence to Waynesburg is hilly, not well cleared, and furnishes no good exposures.

Waynesburg.—The following section was measured upon the S. fork of Ten-mile Creek, a mile below the town, in descending order beneath the soil:—

Slaty Sandstone ; thin blue Slate, 15 feet. *Limestone,* 3 layers, 4 feet. Shale, soft, bluish-black, 4 feet. *Limestone,* three layers, 4 feet. Blue Shale, with row of hard limestone blocks, 3 feet 2 inches. *Coal,* impure, 20 inches. Blue Shale, friable, full of calcareous concretions, 7½ feet. Sandstone, massive, 2 feet ; slaty, 2 + feet.

The Waynesburg Coal-bed is exposed for 2 miles along Laurel Run, which enters the creek from the S. 2 miles below the town.

At the bank at the mouth of the run are seen slaty sandstone, 20 (?) feet ; Brown slate, hard, and in part friable, 3 feet ; *Coal,* in the water, 2 feet exposed.

The slate above the coal is very hard and ferruginous, shows surfaces of about 3 feet in length, and 6 inches in breadth, and contains beds of a true conglomerate, full of rounded pebbles, showing the action of water at the time of its original deposition. It contains flags of an impure pyritous iron-ore, 6 inches long by 1 inch thick, and of silvery lustre. These are abundant in the shale that immediately overlies the coal, which, as here exposed, is probably but the upper member of the bed separated from the lower by an undermining of clay-slate.

Ingram's Coal.

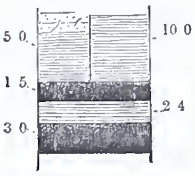


Fig. 545.

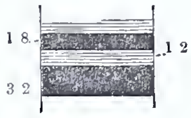


Fig. 546.

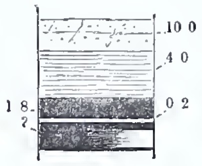


Fig. 547.

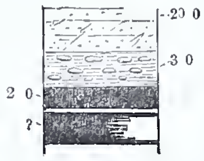


Fig. 548.

The strata undulate irregularly, and at a coal-opening one mile higher up the run, dip 10° N. 30° W. Here a section of the bed reads,—

Sandstone, 10 feet ; Shale, very brown and friable, 4 feet. *Coal,* 20 inches ; Clay band, 8 inches ; *Coal,* 1 foot exposed.

The whole bed is opened at the next bank, and seen to be 6 feet thick ; thus :—

Coal, 20 inches ; Clay, 14 inches ; *Coal,* 3 feet 2 inches.

The pure soft clay between the parts of the bed varies so as to be sometimes but 6 inches thick, and would probably make good fire-brick. The coal is very good.

At Ingram's, half a mile higher up, the dip is S. 20° W., and a section beneath the sandstone and shale (10 feet) reads as follows :—

Coal, 17 inches ; Clay, 2⅓ feet ; *Coal,* 3 feet.

At another opening the sandstone is exposed 10 feet, and the shale is but 5½ feet thick. The various measurements are given in Figs. 545, 546, 547, and 548.

A coal-bed, imperfectly displaying 3 feet of coal, has been opened at the top of a hill just S. of the creek, and about a mile E. of Laurel Run, upon which the openings last mentioned are situated. If this be the Waynesburg Coal-bed, then, as it is so much above those openings, and at the same time dips Eastward, we may look for a slight anticlinal axis traversing this region between the two localities.

CHAPTER XXIX.

COUNTRY SOUTH OF THE CONEMAUGH, IN THE FIRST AND SECOND BASINS, IN SOMERSET AND FAYETTE COUNTIES.

As this region has been more minutely described in Subdivision II. of Book IX., or in the preliminary general description, than other portions of the great bituminous-coal country, little remains to be added except such groups of vertical columns as may serve to illustrate the text. The same order that was then adopted will therefore now be observed in describing the sections of the strata.

First or Salzburg Subdivision of the First Basin.—The following section of the strata, on Elk

Lick Creek, in the S. part of Somerset County, was referred to in the general description—(see Figs. 549 and 550):—

Great Limestone, several feet of it left upon the top of the hill between Elk Lick Creek and Castleman's River. *Coal*, thickness unknown (Uniontown Coal). Interval, Sandstone 50 feet. *Coal*, large bed (Sewickly Coal); Coarse Pittsburg Sandstone, 25 +; Black Shales and Slates, 15 feet. *Pittsburg Coal*, 9 feet. Interval, in which iron-ore fragments lie scattered, 60 feet; Black Slate, 6 feet. *Barren-Measure Coal*, 1 + foot; Sandstone, 30 feet; Black Slate, 20 feet. *Barren-Measure Coal*, 1½ feet; Black Slate, 35 feet; Sandstone, 12 feet; Slate, 1 foot; Black Slate, 1 foot. *Barren-Measure Coal*, 2 inches; Olive Slate, 10 feet. *Elk Lick Coal* (in the ravine back from the W. side of the creek), 4 feet; interval, pink shale, clay, 12 feet. *Coal* (not good), 12 inches; Shale, including blue carbonate of iron (in the road), from 3 to 4 inches, 10 (?) feet. *Coal* (?); interval, of which the lower part is shale, black and buff slate, 30 feet. *Upper Freeport Coal*, not good, and in two beds, 2 feet. *Freeport Limestone*, 5 feet; Coarse Sandstone, 25 feet.

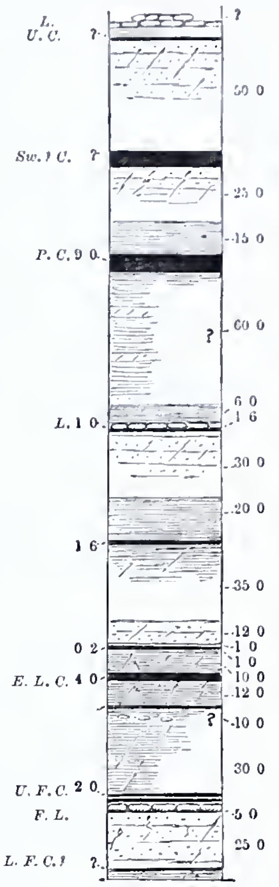


FIG. 549.—Elk Lick Creek.

Lower Freeport Coal (?).—Massive sandstone to the bed of the creek, at a point half a mile below the old waggon-shop. If the limestone seen at the old salt-boring be the Freeport Limestone, the section (as given by Mr Jager) of rocks bored through will continue as follows (see Fig. 550):—

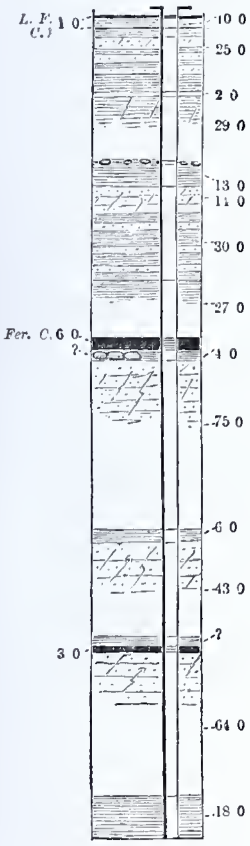


FIG. 550.—Elk Lick Creek, Salt Well.

Freeport Limestone, black, and slate, 2 feet; Interval, 18 feet. *Lower Freeport Coal*, 1 foot. Blue Slate, 10 feet; Dark Shale and sandstone, 25 feet; Fire-clay, 2 feet; Soft argillaceous Shale, 29 feet; Layer of Iron Ore; Black Slate, 13 feet; Grey Sandstone, 14 feet; Argillaceous Shale, 30 feet; Black Slate, 27 feet; Iron Ore, finest quality of blue carbonate, compact layer, 7 inches; Slates, 12 inches. *Coal*, 6 feet; Black Slate, 4 feet. *Tionesta* (?) *Sandstone*, 75 feet; Dark Slate, 6 feet. *Seral Conglomerate* (?) 43 feet; Shale (?). *Sharon* (?) *Coal*, 3 feet; Sandstone, 64 feet; Black Slate, 18 feet.

The Pittsburg Coal-bed has been opened on Keim's land, and on that of Mr Livergood. On Piney Run, 2½ miles S. of Salzburg, there is a slightly fossiliferous limestone 10 feet thick, and dipping N.W: it has been quarried for the National Road. Its roof is a beautifully-variegated sandstone, above which lies a red calcareous sandstone. For 60 feet beneath the limestone occur sandstones, and half a mile down the run appears a fossiliferous limestone and slate. Precisely similar appearances occur in the valley between Negro Mountain and Winding Ridge, in a field. Near Berlin, below the town, a coal-bed about 5 feet thick has been opened, with a floor of black slate 6 inches thick. About 30 feet below it occurs a bed of nearly equal size, and another still lower in the series. A bed of limestone, supposed to underlie the middle coal, would identify it with the Upper Freeport Bed (see Fig. 551).

This limestone (or perhaps a lower one) is seen upon Castlemary River, at the mouth of Buffalo Lick Creek, where it is 5 feet thick, and has a coal-bed over it.

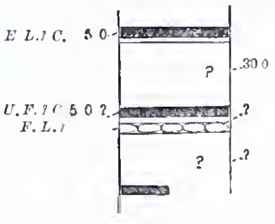


FIG. 551.—Berlin.

The most important deposit of iron ore hitherto brought to light, in this basin, is that of the Elk Lick Falls above referred to. There are here three layers of ore. The lowest, measuring 1 foot 4 inches, is a nearly solid bed, merely divided into blocks rounded at the edges. The other two overlie the first at a distance of 2 feet, and together contain as much ore as would be equivalent to a solid band about 4 inches thick. An ore, supposed to be the same band, was discovered 2 miles farther down the creek. Several thin seams of ore likewise occur on Tubmill Run, half a mile below the sawmill, but they are not of sufficient importance to attract attention. At another place on the same stream, ore is said to have been opened in a position 25 feet below a coal-seam 3 feet 3 inches thick, identified with that at the falls: this ore is stated to amount to 15 inches.

The falls of Elk Lick are a succession of many small and rapid leaps, winding in a long descent through a narrow irregular channel in the sandstone; the rocky walls sometimes overhang the stream, which is then darkened by the meeting boughs of the trees and the tangled stems of the laurel, which in many places make an almost impenetrable thicket. The defile itself is alternately contracted into short narrow passages, and widened into more spacious chambers. The whole scene, though of limited extent, is striking for its novel and picturesque beauty, and in perfect keeping with the wilderness around.

Second and Third Divisions of the First Basin.—On the top of the Alleghany Mountain, 2 miles S. of the Old Portage Railroad, is a bed of blue flag-limestone from 5 to 6 feet thick, supposed to be the Ferriferous Limestone.

The following section (Fig. 552) is descriptive of the strata exhibited on the Alleghany Mountain, at the Pennsylvania Railroad Tunnel:—

At West End of the Tunnel.—Soil; Argillaceous Sandstone and shale, 8 feet; Sandy Shales, with balls of rough ore, 10 feet. *Coal,* 10 inches; Calcareous Fire-clay, 3 feet; Sandy Shales, 10 feet; Light grey Sandstone, 4 feet; Fire-clay Shales, 6 feet; Olive Shale and argillaceous sandstone, 12 feet to railroad-level; Interval, 40 (?) feet.

East End of the Tunnel.—*Coal,* 5 feet, said to be 80 feet below the upper coal in the air-shafts; Coarse Fire-clay, 3 feet; Sandy Shales, 7 feet; Argillaceous Limestone, some beds pure, 10 feet; Sandy Shales and argillaceous sandstone, 30 feet; Interval, 30 (?) feet. *Coal,* 3 feet; Interval, 80 (?) feet. *Coal,* 2 feet in the railroad-cutting near Bennington; Shale, 15 feet. *Coal,* 3 feet 6 inches at Bennington; at R. Lemon's, foot of Plane No. 6, 3 feet coal, 1 foot slate, 2 feet coal; Shales, 10 feet; Sandstone, including beds of blue slate, 45 feet; Black Slate; Ferruginous Shale. Still lower a coal-seam 1½ feet thick is said to exist.

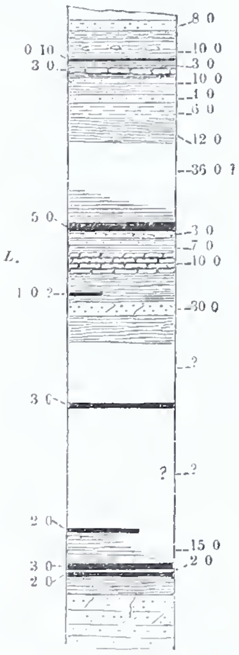


Fig. 552. — Alleghany Summit, Pennsylvania Railroad.

The large bed cut at the E. end of the tunnel contains two bands of slate, but nearly 5 feet thickness of coal. It is mined at the tunnel by the Alleghany Coal Company. The coal is exceedingly columnar and soft: the fissures are at right angles and parallel with the strike. The same bed is wrought by Samuel Lemon at the top of Plane No. 6; its dimensions there are as follows:—

> Coal, 2 feet 10 inches; Slate, 1 inch; Coal, 16 inches; Slate, 3 inches; Coal, 6 inches; dip, 2° to 3° N.W.

It is also wrought by Mr Bingham at the foot of Plane No. 5; also by Moore and Ray, Dougherty and others, farther W.

The lowest coal of the section is that wrought by Messrs Lemon and Miller, near the foot of Plane No. 6. A slate band from a few inches to 2 feet in thickness divides the top bench 3 feet thick from the bottom 2 feet thick. At Bennington the same bed is wrought to supply Harriet Furnace. It is there 3 feet 6 inches thick, and is overlaid at 15 feet distance by a smaller bed from 18 inches to 2 feet in thickness.

Near Lilly's Station of the Pennsylvania Railroad, a seam, equivalent, we think, to the Big Coal of the tunnel, and 4 feet 4 inches in thickness, is mined and coked by Mr Tiley. It is overlaid by blue shaly slate containing some nodular iron-ore, and underlaid by the following strata:—

> Slate, &c., 20 feet; Limestone, quality not tested, 10 feet; Fire-clay, 2 feet; *Coal,* 2 feet; Fire-clay, 2 feet; Limestone.

Tiley's Seam contains 1 inch of slate 18 inches from the bottom; it is worked by Michael Myers, about a mile W. of Lilly's; also by Stephen Myers and David Fox, on land owned by Mr White.

At the head of the Old Portage Plane, No. 3, a seam of coal 18 inches thick is clearly exposed, underlaid by a band of limestone of about 4 feet in thickness. This small seam clearly overlies Tiley's by as much as probably 50 or 60 feet. In a cutting at the foot of Plane No. 3, Tiley's Bed, and also two subjacent seams, are brought to view. The first of these measures 2½ feet in two benches: it is underlaid by fire-clay, and a bed of impure limestone and shale containing nodules of iron ore, to a depth of about 40 feet. A bed of coal 2 feet in thickness succeeds, underlaid by slate.

At Plane No. 2 a limestone appears, judged to be that just described at the head of Plane No. 3.

Between Plane No. 2 and the village of Jefferson no productive coals are visible along the railway, the principal exposures consisting of fine blue sandstones and shales. In the latter an 8-inch seam of coal is visible at one locality. Approaching Jefferson on the Portage Railroad, one or two important beds of limestone outcrop: the upper of these is 3 feet thick, and somewhat slaty in character, but the lower presents a thickness of 10 feet. Between the two a thin bed of bituminous shale is interposed. The dip is about 3° W.

Resuming the line of the Central Railroad from Jefferson, the exposures consist at first of olive and brown shales, capped by sandy shales and fire-clay containing some nodular iron-ore. This fire-clay occupies the centre of the basin on the road. The synclinal axis of the basin thus alluded to is little less than a mile W. of the village of Jefferson. The dips on its W. side amount to about 8° in a direction S. 75° E. This inclination of the beds, it will be observed, is steeper on the W. side of the axis, and speedily brings to the surface the limestone and thin coals seen E. of Jefferson.

The lower coals are nowhere visible on the railroad, but they outcrop doubtless at points not exposed by any cuttings in the railroad or vicinity. An opening has been made by Mr Croyle on a coal 4 feet thick, at a point about three-quarters of a mile N.W. of Croyle's Mills (now called Summer Hill). This opening is high on the hills, probably upwards of 100 feet above the level of the creek at Summer Hill. At Summer Hill Station the strata exposed are olive sandy shales containing some iron ore—not enough, however, to be profitable—underlaid by a thin band of limestone and a small coal. The only workable seam of coal seen in the neighbourhood of the railroad is about a mile W. of Summer Hill, where a 3½-feet seam was opened some years ago on the line of the Portage Railroad.

At the South Fork Station red shales and sandstones begin to make their appearance; these are succeeded by cross-bedded grey sandstones—some beds very coarse and pebbly—to the Big Viaduct, where Umbral red shales and an underlying bed of calciferous sandstone are elevated to the creek-level by an anticlinal arch. The inclination of the strata on both sides of the viaduct axis is very gentle, not exceeding 2° or 3°. The consequence is, there are no exposures of workable coals until the vicinity of Conemaugh Station is reached. Here a coal 3 feet in thickness is opened near the station, and higher in the hill a seam of coal underlaid by hydraulic cement, and known as the cement seam of Johnstown.

The accompanying section (Fig. 553) will exhibit the succession of strata in the vicinity of Johnstown :—

Limestone, 1 foot 6 inches to 2 feet; interval. *Coal,* 6 inches; interval, 12 feet. *Iron Ore* in two bands, 2 feet to 3½ feet; interval, 60 feet. *Coal,* 3 feet 8 inches; interval, iron ore, &c., 45 feet. *Coal,* 2 feet 6 inches; Slate, 18 inches; Limestone, 3 feet; Shale, 28 feet. *Coal,* 8 inches; Shale, 12 feet. *Coal,* 3 feet 6 inches; Fire-clay, Stigmaria rootlets, 1 foot; Calcareous hydraulic cement, 4 to 5 feet; Shale and Fire-clay, 10 feet; Shale, including 6 to 12 inches of iron ore, 50 feet. *Coal,* 3 feet 3 inches, at or just below water-level; interval, including two thin coaly bands, 45 (?) feet; Seral conglomerate.

By adhering to the limestone bands as fixed horizons, we are here greatly puzzled to affix names establishing the identification of the coal-beds. Should a limestone stratum be found under the upper 3 feet 8 inch coal, and that under the next subjacent coal prove only local, the difficulty vanishes, and we have the proper seams of the Freeport group.

The iron ore near the top of the section is worked extensively at the Cambria Iron-works near Johnstown.

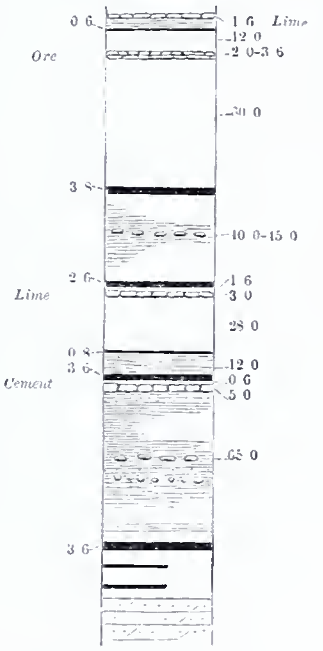


FIG. 553.—Johnstown.

The stratum overlies the highest workable coal about 60 feet; it is therefore high in the hills above Johnstown. Although mined for a long time on the N. side of the Conemaugh, it has not been detected on the S. side in its full thickness: examinations have been made for it. The stratum has a roof and floor of slate, and is divided into two bands differing in character and thickness. The upper band varies in thickness from 18 inches to 2½ feet. Under good cover it quarries in square blocks. It is close-grained, compact, dove-coloured, oxidises at the outcrop, forming a Spanish brown, and at the outcrop is always shelly. Analyses prove it to contain from 51 to 52 per cent of iron. The lower band, separated from the upper by a thin band of bluish indurated fire-clay, varies in thickness from 6 inches to 2 feet; colour, a light-blue limestone, weathering white on the surface. It is worthy of remark that where the upper band thins the lower thickens, and *vice versâ;* so that the average total thickness of the band is from 2 to 3½ feet. The Cambria Iron Company work this ore with coke, and sometimes without limestone.

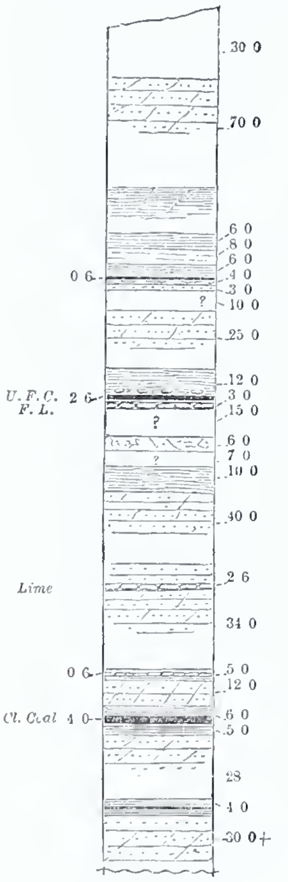


FIG. 554.—Stony Creek.

Between Johnstown and the flank of Laurel Hill, the Coal-measures occupy a flat shallow basin. On the Eastern side of the basin the dips are very gentle, so that the Johnstown ore-band occupies a high position in the hills bordering the river. The bottom rock of the Coal-measures, in the form of a coarse-grained grey sandstone, 40 feet in thickness, rises to the surface near the seventy-sixth mile-post of the railroad.

On the E. slope of Laurel Hill, 2 miles from Cambria Furnace, red iron-ore is found and wrought, associated as follows:—White Sandstone, 10 feet; Red Shale, 8 feet; Red Ore, 16 inches; Blue and red Shale. This Umbral red ore is mined and used at Laurel Hill Furnace, 6 miles S.W. of the Conemaugh, on the N.W. dip of Laurel Hill. The bed is 12 or 18 inches thick, capped by red shale, and underlaid by white and red clay. A thick-bedded white sandstone is cut through to reach the ore beneath, which makes a good metal. A section was made on Stony Creek, at the Red Bridge, above the mouth of Ben's Creek, Fig. 554; it reads as follows:—

From top of the hill to a terrace, perhaps containing coal, 30 feet. Thin-bedded coarse Sandstones, under it large masses of Shale, in all 70 feet; Brown and black Shales, 6 feet; Buff and olive Shales, 8½ feet; Green Slates, 6 feet. *Coal,* 6 inches; Fire-clay and Shale, 4 feet; Sandstone, 3 feet; Unknown, 10 feet; Sandstone, thin-bedded, 25 feet; Slates and Shales, 12 feet; Ore stratum, 3 inches; Fire-clay, 8 inches. *Coal,* 2½ feet; Black Slate, 6 inches. Limestone, 3 feet; Unknown, 15 feet; Massive Sandstone, with some shale, 6 feet; Unknown, 7 feet; Blue and grey Shales and slates, 10 feet; Thin Sandstones, 40. Limestone, 2½ feet; Sandstone, massive in lower part, 34 feet; Blue Slate, with half an inch of limestone, 5½ feet; Massive Sandstone, 12 feet; Shale, 2½ feet; Black Slate, 3 feet; *Clarion* (?) *Coal,* good, pyritous, 3 feet 9 inches; Black Slate, 5 feet. Massive Sandstone (at the abutment of the Red Bridge), 28 feet; Black Slate, 4 feet. *Brookville* (?) *Coal,* 12 inches; Sandstone, 30 feet exposed. In all, 390 feet of rocks.

A section made half a mile W. of the latter, and upon the slope of the "Hog's Back," reads as follows, and is exhibited by Fig. 555:—

Sandstone, flaggy, 30 feet. Sandstone, massive, and Shale, 60 feet. *Coal* (?) terrace; Sandstones, thin-bedded, no exposures, 45 feet. *Pittsburg* (?) *Coal* (?) terrace; no exposures for 150 feet, except some coal-slates and brown ferruginous shales; Sandstone, massive and flaggy, 36 feet; Olive Shale, 6 feet; Dark-blue Shale, 4 feet; Sandstone, with some balls of ore, 25 feet; Dark Shale, 3 feet. Iron ore, nodules in contact, 12 inches. Limestone, hard and ferruginous, 2½ feet; Fire-clay, 2½ feet; Olive Shale, 4 feet; Coarse grey heavy Sandstone, 11 feet; Black Slate, 11½ feet. *Coal,* 4 feet; Slate, 3 inches; Limestone, 6 feet; Blue-black Shale (ore 5½ to 12 inches), 8 feet; Dark-blue Shale (ore 1 or 2 inches), 7 feet; Shale (ore one band), 1 foot; Thin sandy Slate, 13½ feet. *Coal,* 9 inches; Shale, blue and sandy (ore two bands, 2 feet apart, 2 inches thick each), 14½ feet. In all, 445 feet.

The structure of this section seems to identify its coal and limestone with the ferriferous coal and limestone of the Clarion group. The dip known is Westward (in one spot 11°), and they may belong to the Freeport group.

On Livergood's land is a coal-bed 4 feet thick, with large quantities of iron ore in a 7-feet stratum of shale above it; upon this rests a massive sandstone stratum; and 60 feet farther down in the series is another coal-bed, unexplored.

Two beds of coal and limestone, each 3 feet thick, occur 1½ miles N.E. of Johnstown; ferriferous slate here overlies the coal.

The same slate, exceedingly ferriferous, occurs above the coal and limestone on Stony Creek, 2½ miles above Johnstown. The column (Fig. 556) represents a section constructed between the confluence of Paint Creek with Stony Creek, and the Paint Creek Falls, and reads as follows:—

Sandstone, 5 feet, including scattered balls of iron ore of no great value, but amounting in all to perhaps 12 inches in thickness. Iron ore, nodular, 12 inches. Sandstone, 3 feet. Iron ore, nodular, good, 5 inches; Sandstone, 2 feet. Iron ore, balls close and persistent, good, 4 inches; Shaly Sandstone, 9 inches. Iron ore, compact stratum, of excellent quality, 2½ inches. Sandstone, 6 inches. Iron ore, compact stratum, good, 1½ inches; Fine-bedded Sandstone and Shale, 6 feet; Shale and Slate (ore scattered throughout, of the finest quality, and in all perhaps 6 inches), 4½ feet. Slate, black laminated, 2½ feet; *Clarion* (?) *Coal* (dipping S.E. 3°), 3 + feet; Sandstone, massive, and also thin-bedded, which forms the cascade, 40 + feet. Level of bottom land, where perhaps a thin coal-bed exists; Sandstone, skirting the creek, with cliffs, massive, 40 feet; Iron ore, finest quality, of blue carbonate, compact layer, 7 inches. Massive Sandstone, also thin-bedded, including 8 inches of coarse nodular carbonate of iron, 30 feet; Shale, 5 feet; Sandstone to the mouth. The rock is falsely bedded, indicating variable currents of deposition; it frequently presents conglomeritic aspects, and may be the Seral conglomerate. The falls are perhaps 10 feet high.

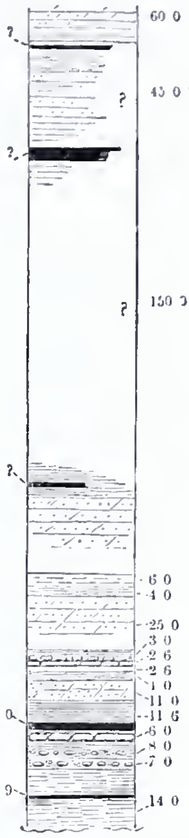


FIG. 555. — Below Red Bridge, on Stony Creek.

At the forks of Paint Creek, as the section exhibits, there is at the sawmill an abundance of good ore, 2 feet thick, partly "rock ore," or continuous strata, and partly very continuous ball-ore, within a space of 8 feet. Besides these there are beds of large nodules in the 5-feet sandstone roof, and a very good ore in the 4½-feet shale below. The lower band farther down the creek affords masses of many pounds' weight, lying almost loose in the bed of the creek; but it cannot be mined, because it seems to be included between hard massive sandstones. This may prove, upon trial, to be merely an appearance due to the enormous amount of fallen rocky matter which lines the sides of the gorge through which the stream now flows.

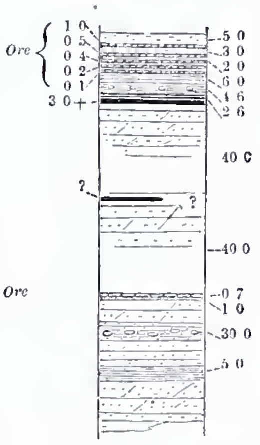


FIG. 556.—Paint Creek.

Two coal-beds and two limestone-beds outcrop upon the hill at the dam on Stony Creek, 2½ miles below Paint Creek. The section is as follows:—

Sandstone in fine slabs, forming the summit of Bell's Knob, near Rhoad's Camp Creek, 40 feet. *Coal terrace and outcrop;* Shales, olive (fragments of iron ore), 18 feet. *Coal* (?) *terrace* (little black Slate); Shales, olive, 60 feet. *Coal* (?) *terrace;* Sandstone, blackish, 15 feet; Shales, pink, yellow, olive, with fine-grained Sandstones, 75 feet. *Coal terrace*, 10-feet slope, in which occurs either the large bed mined on the opposite side of the creek, or else the small bed opened in the mill-race, 1 foot thick; Seral conglomerate, exposed, 70 feet.

From the top of Link's Hill, upon the left bank of the creek, we have the following section—(See Fig. 557):—

Coal (?) *terrace*, 60 or 80 feet below the hill-top; Sandstone, 35 feet; Olive Shale, sandstone, and some black slate, 10 feet; *Brookville* (?) *Coal* (dip. S.W. 10°), 5 feet.

This may be the bed of that terrace above alluded to, which appears 50 feet above the road leading Southward to the Somerset Road, in which case the S.W. dip must be very local, and the section continues downwards, thus:—Sandstone, 45 feet.

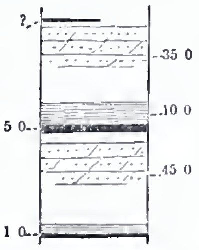


FIG. 557.—Rhoad's Camp.

Coal (?) terrace, with springs running up through the orchard, and doubtless the same little coal-bed which is opened in the mill-race. This coal-bed appears in the run back of Mr Link's fields, where above it occurs a band of very fine ore 3 inches thick.

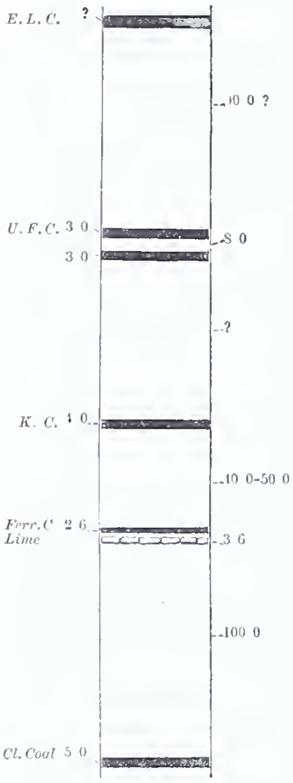


Fig. 558.—Stoystown.

In the narrow middle trough of Somerset County, the Clarion Coal-bed (see Fig. 558), has been developed in may places along Little's Run, 4 miles N. of Stoystown. The bed here contains 5 feet of good coal. Separated from this by 100 feet of strata, we find the Ferriferous Coal-bed here 2½ feet thick, and resting immediately on the Ferriferous Limestone, from 3 to 4 feet thick. The place where this appears is 2½ miles N. of Stoystown, at Lohr's limestone quarry.

The Kittanning Coal-bed is worked by Mr Kimmel at Stoystown, where it is 4 feet thick, and overlies the last at an interval estimated to be from 40 to 50 feet.

The Upper Freeport (?) *Coal-bed* is divided, in the vicinity of Stoystown, into two beds 8 feet apart, and each of them 3 feet thick. The lowest of these is worked on a little branch of Oven or Breastwork Run, about 2 miles N.E. of Stoystown.

There is an outcrop of apparently a large coal-seam on the turnpike E. of Stoystown, overlying the uppermost of these beds at a distance of about 90 feet. This is probably the Elk-Lick Coal-bed. Benches or indentations on the surface indicate the existence of two or three other coal-beds between this and the summit of the highest hills, though the localities where the coal has been opened are so scattered and few as to interfere with all attempts at placing them accurately in the series.

A small quantity of iron ore reposing upon the Clarion Coal at the railroad summit, and near Summer Hill, becomes in the vicinity of Stoystown a regularly-formed band of nodular ore. This is evident from fragments seen in the bed of the small creek on which Little's Coal-bed is opened.

A band of sandstone seen over the same coal-bed at Plane No. 1, and at Stony Creek bridge, appears in corresponding place over Little's coal.

Two small beds are seen under the Ferriferous Limestone, 3 miles N. of Stoystown.

The 30-feet sandstone over the Ferriferous Coal makes its appearance here.

Although the old Shade furnace was supplied with a poor ore, which led to its abandonment, there occurs an abundant deposit of pretty good ore, discovered 2 miles farther up the stream. It is in coarse nodules, some of which are of great size, though a small layer of a finer quality, and a few inches thick, overlies it in a compact shale at a distance of 4 or 5 feet. Between 10 and 15 feet above this latter layer there is a thin seam of coal about 16 inches thick. No other coal-bed, and unfortunately no limestone, has yet been, or is likely to be, discovered in this immediate neighbourhood. Notwithstanding the scarcity of these materials, the spot seems a sufficiently favourable one for the manufacture of iron—the ore appearing to be good and abundant, and fuel, both charcoal and mineral coal, being procurable at no great distance: a small furnace has therefore been erected at this place. The geological situation of this ore is in shale, resting directly on the upper surface of the coarse Seral conglomerate. Indications of the same ore occur in a corresponding position, the whole way from the old Shade furnace to the mouth of Shade Creek.

At Lambert's mill there is a bed of coal 3 feet 7 inches thick, and over it 12 feet of dark shale, containing a yellowish fine-grained ore, in flattened nodules, weighing from 10 to 20 lbs. The aggregate thickness of the ore, in the whole 12 feet of shale, is estimated at 2 feet. Ten or twelve feet beneath the coal-bed lies a band of limestone, in thickness about 2 feet.

A locality important for its iron ore is on Wells' Creek, 5½ miles N.E. of Somerset. Here a layer of limestone occurs in the bed of the creek, resting on a blue sandstone, which forms the bottom of the channel. The limestone is said to be in all 6 feet thick, though only 2 feet are exposed. A coal-bed showing a promising outcrop appears a few feet above the limestone, and indications of other coal-seams present themselves farther up the hill. One of these upper beds has been worked. At the top of the hill, nearly 300 feet above the stream, in a sterile tract of a few acres, many pieces of a very rich red ore have been met with, but the quantity remains unknown. This spot deserves examination. Should the ore be abundant, its value would be enhanced by its proximity to another deposit of ore on Stony Creek, with which it might be worked. A furnace is much wanted in this part of the country, where charcoal and water-power are both plenty.

The ore just referred to on Stony Creek is at the "Silver Diggings," about 2 miles above the mouth of Wells' Creek. Here a shaft 28 feet deep was found, which passed through two bands of ore, the lowest of which, lying lower than the bed of the creek, cannot be worked. The upper, though a small seam, consists of very pure ore. This is of insufficient thickness by itself, but at the upper edge of the shaft there is another layer of ball ore, apparently of ample size, possessing an aggregate thickness of ore equal, we think, to 1 foot.

Along the turnpike W. of Somerset village the following section was made, which only approximates to the truth. It begins at a point 2¼ miles E. of Laurel Hill Creek on the top of a steep hill, where the exposures are—

Shale, 6 feet; Hard grey Sandstone, passing into shale (affording a good example of the facility with which this change seems to have occurred in the original deposition of all these argillo-silicious rocks), 7 feet; Black Slate, 6 inches; Variegated Shales, 10 + feet. To the Eastward are seen (how far beneath the last-mentioned strata is uncertain, but not 100 feet) contorted sandstone, 40 + feet; and Shale, 15 + feet. *Coal terrace;* Shales, 50 feet. *Coal terrace;* thinly-bedded Sandstone, 60 feet; Red and variegated Shales, 30 feet. These are within 2 miles of Somerset. All these rocks dip scarcely 2° towards the N.W.

At Laurel Hill Creek, near Milford, the following section (see Fig. 559) was obtained:—

Shale, olive and blue, hill-top, 18 feet. *Coal,* slaty and poor, 1½ feet; Olive Shale, with a little red shale, 15 feet; Sandstone, easily traced, 20 feet. *Coal,* thickness unknown; Red and variegated Shales, 25 feet; Olive and blue Shales, 25 feet. *Coal,* thickness unknown; Sandstone, 8 feet; Shales and Sandstone, 20 feet.

The uppermost coal is seen terracing the hill above Mr Hershberger's sugar camp; the third bed (descending) is seen at his spring house, and ranges high up in Mr Scott's fields; the fourth coal was opened, 1½ feet thick, at Mr Scott's house.

A coal-bed, probably higher than any in this vicinity, is seen at Mr Taylor's spring, near his dwelling, 1 mile from Milford, and ranges away in a terrace W. of his house. One of the most beautiful instances of the regularity with which the soft coal and accompanying black shales, and still softer fire-clays, are denuded along these horizontal outcrops, while the harder rocks above them form a steep slope, and the harder rocks below a gently-sloping terrace in front, may be viewed upon the road to Centreville, about 1 mile from Milford, perfectly well defined, and extending with surprising symmetry for a great distance.

On Ben's Creek, the second and third coals (Ferriferous and Kittanning coals) are each 4 feet thick, and the Ferriferous Limestone 3 feet, well exposed on the turnpike from Johnstown to Somerset, where, in a few dozen yards, it becomes a stratum of workable carbonate of iron. The Kittanning Coal appears for a fourth of a mile along the turnpike leading to Ligonier, the grading of the road conforming itself to the dip.

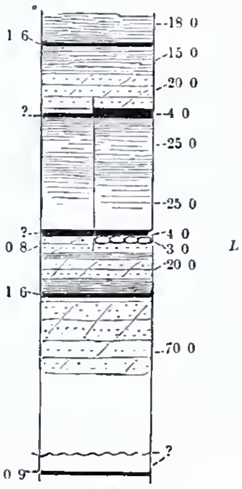


FIG. 559.—Milford and Ben's Creek.

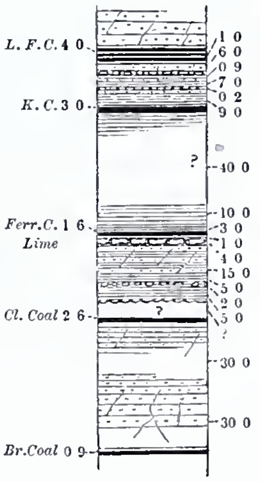


FIG. 560.—Laurel Hill Creek.

Along Roaring Run, from its mouth to the bridge on the Jennerville Road, a sandstone, the upper member of the Seral conglomerate, fills the bed of the stream. A small exposure occurs at Griffith's mill, near the road. Descending the road from the N. to the bridge, we cross the outcrop of a coal-seam, which was ascertained to be the Clarion Coal. It is mined 2 miles N.E. of the mill, where it yields 3 feet of rather indifferent coal. Slate and shale occur above it through a thickness of 50 feet. Covering the surface of these slates we found much iron ore of excellent quality. In the hill W. of this a massive sandstone, 25 feet thick, overlies these rocks. This, following it still W. towards the middle of the basin, seems to change in character, and we are therefore deprived of any key it could afford us to the overlying coal-beds. The facts collected go to show that the Kittanning Coal-bed, 4½ feet thick, opened 2 miles W. of the bridge, and a band of limestone 3 feet thick, underlying it, range extensively through the basin, their outcrop appearing along the streams. Above these we meet with indications of several other coal-seams, the exact number and thickness of which could not be ascertained. At the mouth of Lick Run, on Ben's Creek, there is a limestone, 5 feet thick, apparently in this part of the series.

The following section (see Fig. 560) was obtained at Husband's mill, on Laurel Hill Creek :—

Lower Freeport Coal, 2 feet ; Slate, 2 inches ; *Coal,* 6 inches ; Fire-clay, 1 foot ; *Coal,* 18 inches ; Fire-clay, 2 feet ; Calcareous Sandstone, 6 feet. *Iron Ore,* in large nodules, closely packed, 9 inches ; Slaty Sandstone, 7 feet. *Iron Ore* (good), 2 inches ; Sandstone, 2 feet ; Fire-clay, 1 foot ; Blue Shale, 6 feet. *Kittanning Coal* (good) 3 feet ; Strata unknown, 40 (?) feet ; Blue Shale, 10 feet ; Black Slate, 3 feet. *Ferriferous Coal,* 1½ feet ; Fire-clay, 12 inches ; Ferriferous Limestone, 4 feet ; Slaty Sandstone, 15 feet ; Shale, with balls of *Iron Ore,* of variable quantity (but amounting sometimes to 2 feet), 5 feet ; Shale, 5 feet to water-level.

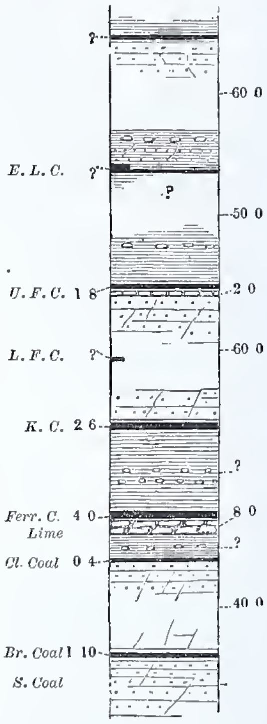


FIG. 561.—Castleman's River.

Castleman's River, at Shaf's Bridge, flows in the Seral conglomerate, the lowest coal-bed ranging at a height of 100 feet above the water, and it continues to flow in it as far as Snyder's, the dip being 5° to the N.W. The coal enters the water half a mile below, and was once opened upon the left bank, and was 22 inches thick.—(See Fig. 561.)

The Ferriferous Coal-bed descends close to the water at the double bend, a mile and a half below, but rises again as the rapidly-falling stream returns upon and recrosses the lower strata, causing the first coal-bed to re-emerge below the coal-bank, near the forge at Took's Run.

Below this, flowing in the Seral conglomerate, the stream has its bed full of huge masses of fine-grained homogeneous conglomerate, fragments of that formation. Even the Umbral red shales must appear in the little run which enters at the head of the sharp bend.

At McMullin's the first coal-bed appears again in the bed of the stream at two points—one about three-fourths of a mile above the mill, and another a mile below it, as seen on the right bank ; it again appears in the bend at Mr McClintock's spring. The river flows in the conglomerate to its mouth.

Section near Shaf's Bridge :—

This begins above with fine-grained sandstone, and contains balls of poor ore, 35 feet, lower part shale. *Coal,* 18 inches, exposed—it has a slate roof. Massive Sandstone, 70 feet—rests on the *Lowest Coal,* 22 inches, opened on the stream : it is of good quality. Fire-clay, a few inches ; then Sandstone and conglomerate to the river-bed, 90 feet.

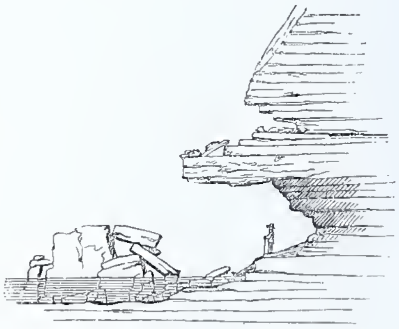


FIG. 562.—Castleman's River and Conglomerate Cliffs (in partial section).

At the head of this section we observed a *coal (?) terrace.* Along the right bank, below the mouth of Scrubglade Run, the sandstone and conglomerate rocks are so arranged, in more and less durable alternations, as to present remarkable overhanging cliffs worn by the yearly freshets which rush down the river-bed in early spring. The annexed sketch represents such a cliff, one layer of which overhangs the river 12 feet.—(See Fig. 562.)

The section at Snyder's is continued towards the top by observations upon the road to the Forge. Mr Weimar's Coal is the third ascending in the series at Snyder's, and the bed in Weimar's orchard is not observed in Mr Snyder's fields.

Freeport Limestone ; fragments found below the variegated shales, with fire-clay and balls of impure carbonate of iron ; the interval not ascertained. *Lower Freeport Coal ;* massive Freeport Sandstone, sometimes conglomeritic, everywhere traceable by the enormous quantity of debris which it has cast down upon all the slopes of Castleman's River and Laurel Hill Creek, 40 feet thick. *Kittanning Coal,* 2½ feet thick ; fine-grained sandstone, containing coarse silicious nodular carbonate of iron, 30 feet. *Ferriferous Coal,* in a terrace 70 feet above the *Clarion Coal,* 18 inches ; this is in a terrace 40 feet above the river-level. This coal has been stripped along the left bank below Snyder's. The Ferriferous Limestone here appears 70 feet above the river, with 20 feet of slates. It occurs at about the same height on the opposite side at Mr Phillips's.

One mile below Mr Snyder's are seen the following rocks in a little stream :—

Massive conglomeritic sandstone (Freeport Sandstone), 30 + feet. *Kittanning Coal;* interval not measured; then sandstone and shales, 10 feet; black slate, 4 feet; ferruginous slate, 1 foot. *Ferriferous Coal,* said to be 2 feet. Interval, 8 or 10 feet. *Ferriferous Limestone,* 3 feet exposed.

At Squire Connelly's are seen the following rocks :—

Shales, &c., 30 feet. *Coal* (Elk Lick), at Mr King's house, with 80 feet of interval unknown; shale, 15 feet. *Lower Freeport Coal,* 20 inches, poor; fire-clay, sandy, 6 feet; massive sandstone, 15 feet; interval, including 20 feet of compact shale, 70 feet; blue shale, 5 feet. *Ferriferous Coal,* 2 feet; black slate, 8 inches; coal, 4 inches; black slate, 12 inches; *coal,* 18 inches, poor; fire-clay, 12 inches. *Ferriferous Limestone,* 8 feet; olive shale, 15 feet, containing good nodular iron-ore in bands amounting to 6 inches total thickness; a peculiar-looking grey-streaked sandstone, 7 feet. *Coal* (?) 4 inches; black slate and shale, with much good nodular iron-ore, 5 feet.

The same rocks are exposed by Spring Run as follows :—

Black slate, 8 feet. *Coal* (?); interval unknown, 6 feet; sandstone, 12 feet; interval, 15 feet; olive ferriferous shale, 15 feet; black slate, 3 feet. *Upper Freeport* (?) *Coal;* Sandstone, 1 foot. *Freeport* (?) *Limestone,* 2 feet; sandstone, 60 feet; shale, 7 feet; grey sandstone, 2 feet; olive ferriferous shales, 9 feet; ferriferous sandstone, 6 feet; black slate, 12 feet. *Ferriferous Coal,* 4 inches; blue shale, 2 feet; *Coal,* 11 inches. *Ferriferous Limestone,* 8 feet; sandstone, 1 foot; shale, 1 foot; sandstone, 6 feet.

At Mr McMullin's the following section was obtained :—

The hills here exceed 500 feet in height. At the top are shales, &c., 35 feet. *Coal;* Shales, &c., 100 feet. *Coal terrace* on a level with the summit of the Fort Hill opposite, and displaying 10 feet of shales, some of which are red. Below are thinly-bedded sandstones and shales, 80 feet. *Coal,* the smut seen at McMullin's barn; sandstone exposed in the road, 20 feet; strata undetermined 30 feet. *Lower Freeport Coal;* soft black slate of roof, 2 feet; slaty sandstone, 30 feet. *Kittanning Coal;* floor, 2 feet of black slate; sandstone, 10 feet; unknown, 50 feet. *Ferriferous Coal;* limestone not exposed; massive conglomeritic sandstone fragments, 50 feet; flaggy sandstone, 6 feet; black slate, 1½ feet; sandstone, 1½ feet; black slate, 4 feet; sandstone, single stratum, 3 to 6 feet thick; immediately over the *Clarion Coal,* which is hard and poor, 1½ feet, including 4 inches of slate; slate, 2 feet; *Coal,* hard, 1 foot; slate, 1 foot; *fossiliferous* obliquely-bedded sandstone, 25 feet.

Here occurs an instance of ancient denudation, producing hollows in the surface of a bed of black slate upon and in which coal was afterwards deposited.—(See Fig. 563.)

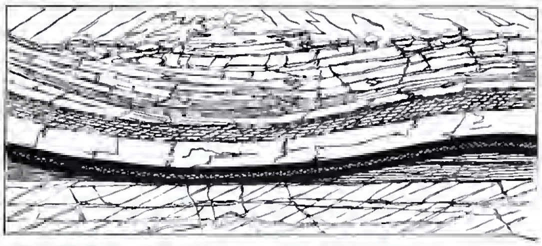


FIG. 563.—Palæozoic Denudation, exhibited on Castleman's River.

A little farther down the river, the same bed appears half out of the water, and only 1 foot thick, roofed by a massive stratum of sandstone, 20 feet thick. The coal is here more slaty, and the sandstone lies immediately upon it, forming, where the coal goes under water-level, a gigantic tessellated pavement for the river, from which rise cliffs upon each shore of thinly-bedded sandstone, the bases of the lofty wooded walls that support the cultivated upland. This pavement is covered by angular fragments of Seral conglomerate, a single one of which will sometimes contain 2000 cubic feet of stone.

At the Turkey Foot, stalactites are seen upon the left bank, pendant from the rocks below the Ferriferous Limestone bed.

On Drake's Run a band of iron ore, 9 inches thick, occurs above the Kittanning Coal, which is 3 feet thick. The same bed of ore is seen at Whipley's on the Clay Turnpike, at the foot of Laurel Hill, and again on Gabriel's Run, S. of the Youghiogheny.

On the Youghiogheny River, 1 mile above Smythfield, a large bed of coal is opened, exhibiting:—Black slate; *Coal,* 15 inches; slate, 1½ inches; *Coal,* 15 inches; fire-clay, 18 inches; *Coal,* 20 inches; slate, 1 inch; *Coal,* 4 inches (in all 4½ feet of coal, enclosing 20 inches of fire-clay and slate); slate, 2 feet; then limestone, of a thickness unknown.

Fifty feet above this coal-bed is seen a slaty limestone, from 2 to 3 feet thick, supporting 3 feet of green shale, and above it massive sandstone.

SECOND BASIN.

On Black Lick Creek, 10 miles W. of Ebensburg, near Lewis and Rodgers' sawmill, the following strata are exposed:—*Coal,* 4 feet (2 inches parting-slate, 18 inches from the floor); fire-clay; some ore. Strata having a thickness of 100 feet bring us to another *Coal-bed,* 3 feet thick; and 50 feet higher, a third *Coal-bed,* 18 inches thick (supposed to be the same as at the hill, half a mile to the W.) A fourth *Coal,* 18 inches thick, lies 30 feet above the last.

On the Old State Road, 7 miles from Indiana, and 2 miles S. of the Clay Turnpike, there is a *Coal-bed,* 4 feet thick, in which, 1 foot from the floor, is a seam of slate, 1 inch thick; roof, black slate.

Four miles S. of the Cherry Tree is a coal-bed, 3 or 4 feet thick; slate roof.

Four miles E. of Indiana are coal and limestone; the former 4 feet thick, and 5 feet above the latter.

One and a half miles W. of Strongtown, on the E. side of Yellow Creek, the same bed appears, 3½ feet thick, with 2 inches of slate, 1 foot from the floor; roof, sandstone.

Limestone lies in the turnpike road, 70 feet above the coal-bed.

Limestone, 5 feet thick, is exposed 2 miles S.W. of Strongtown, the upper part slaty. Thirty feet above it is a quarry of blue micaceous sandstone, used for tombstones and grindstones.

Coal, 3 feet thick, is mined 3 miles S. of this spot; 30 feet above the coal is limestone, and under it lie 3 feet of highly ferriferous slate.

East of *Armagh* are seen indications of a series of seven beds; the Lower Freeport Coal, measuring 6 feet at the foot of the mountain, 1½ miles N. of the turnpike gate, and the Brookville Coal, 3 feet, on Finley's Run. Almost immediately beneath it are seen the sandstones of the Seral conglomerate, 50 feet thick, and farther down the stream are seen the Umbral red shales with their ore. It will be recollected that the Lower Freeport Coal is the Great Bed at Punxutawney.

The following strata are exposed half a mile below the Conemaugh furnace, on the Pennsylvania Railroad, on the W. dip of Laurel Hill:—

Argillaceous irregularly-bedded Sandstone, with nests of red shale, from 40 to 60 feet; *Coal*, divided by 2 inches of Slate, 2 feet 6 inches; Sandy Shale and coarse Stigmaria clay, 7 to 10 feet; Light-grey fine irregularly-bedded Sandstone, with shale partings, 55 to 60 feet; Argillaceous Shales, 15 to 20 feet; *Coal,* 1 (?) foot; Fire-clay, 3 feet; Coal, Shales, and thin flaggy Sandstone, 15 feet; Seral conglomerate Sandstone, lower bed somewhat pebbly, 40 + feet.

The coal worked for Conemaugh furnace, on the W. side of Laurel Hill Gap, supposed to be next to the lowest, has the following dimensions:—

Coal, rather dirty, though good, from 3 feet 6 inches to 3 feet 9 inches; Fire-clay, Shale, Stigmaria, 4 inches; *Coal,* 6 inches.

The bed is very closely fissured with vertical cleavage running nearly up and down the dip.

When this coal is purest, and is carefully coked, 100 bushels yield 130 bushels of good coke, weighing from 40 to 60 lb. to the bushel. It is coked in long heaps containing 2000 bushels. When the coal is coarse and good, from four to six days are required in coking. When fine coal is used, from eight to sixteen days are necessary.

From the cuttings of the Pennsylvania Railroad at and E. of Lockport, the following section (Fig. 564) was compiled; the strata dip gently Eastward :—

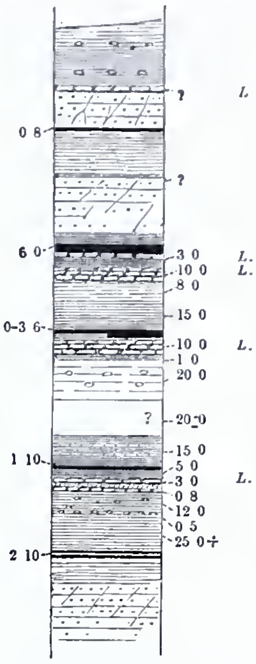


FIG. 564.—Lockport.

Sandy Shale, ore balls in lower part. Dark-blue slate; Olive Shale, containing ore nodules. Limestone, ferriferous; Micaceous blue Sandstone. *Coal*, 8 inches; Fire-clay, ball ore, and Sandstone, 60 + feet. *Coal*, 5 to 6 feet, in three benches. *Silicious Limestone*, impure, 3 feet; Blue Slate, 4 feet. *Limestone*, thin bands in 10 feet; Fire-clay, indurated, 8 feet; Blue Slate, 15 feet. *Coal*, 2 to 3 feet 6 inches. *Limestone*, rotten, ferruginous, 10 feet; Black Slate, 1 foot. Fire-clay, containing ore balls, 20 feet; Interval, 20 feet; Sandy Slate, 15 feet. *Coal*, 22 inches; Slate, 5 feet. *Blue Limestone*, 2 to 3 feet; Hydraulic Cement and iron ore, 7 inches; Olive and blue Shale, with scattered balls, 12 to 20 feet; Iron ore, 5 inches; Shale, 25 + feet. *Coal*, 6 inches; Slate, 1 foot; *Coal*, 2 feet 4 inches; Slate and Sandstone.

At *Centreville*, near the centre of the basin, only the upper coal and limestone are out of the water. The coal, 6 feet thick, emerges half a mile above and 1½ miles below the village; but continuing to ascend the river, all the beds of the foregoing section rise from the river-bed.

Two coal-beds, probably of the Barren series, appear in the hills. Two miles N. of Bolivar, the third coal from the top, or the Kittanning Coal, measures 4 feet. The 4-feet bed of coal, 5 miles W. of Ebensburg, and again 7 miles W. of Ebensburg, based on ferruginous sandstone, exhibiting vegetable impressions,—the former being within half a mile of an exposure of limestone near the Black Lick Creek,—bears doubtless a relation to this part of the general series.

From the vicinity of Fairfield to a little N. of Ligonier there is a belt of country along the middle of the basin, from 2 to 3 miles wide, which embraces the upper strata, the most productive in coal and limestone of any in the valley. The limestone is here more abundant than usual. The following section represents the stratification about 2 miles N. of Ligonier :—

Highest land; Coal (?) bench; Interval, 10 feet. Limestone, tolerably good, 7 or 8 feet; Fine-bedded Sandstone, 35 feet. *Sewickly Coal*, opened 3 feet; Interval, 5 (?) feet. *Limestone*, 8 feet, good, hard, and blue. This is 6 feet at Kieffer's, and elsewhere 4 feet; Shales and black Slates, 10 feet. *Redstone Coal*, 3 feet; Shales, brown and black Slate, 20 feet. *Pittsburg Coal*, 8 feet 3 inches (at Kieffer's, 10 feet; at Giesy's, 7 feet); Interval, 20 feet. *Pittsburg Limestone*, white, flaggy, good, from 4 to 9 feet; Flaggy Sandstone, &c., 20 feet. *Coal*, 3 feet, good; Interval, 8 feet. *Limestone, ferruginous*, 3 feet; Shales, olive and black, 15 (?) feet. *Coal*, only the outcrop visible; Sandstone (Mahoning), 50 feet; Olive Shales, 24 feet; Black Slate, 6 feet. *Elk-Lick Coal*, outcrop only; Interval, 15 feet. *Coal*, outcrop; Olive Ferriferous Shale, 30 feet. *Upper Freeport Coal*, 1 foot. Freeport Limestone, 1 foot.

This section, representing the upper group of coal, taken in connection with that at Lockport exhibiting the lower, furnishes a very complete representation of the whole series of beds composing this coal-basin. In the Ligonier neighbourhood other lower bands were noted, which I have not included in the section, as they did not admit of precise measurements. One of these is a coal-seam, 1 foot thick, corresponding probably to the Kittanning Coal-bed of other localities; another is a coal-seam, the representative of the Brookville Coal, near the foot of Chestnut Ridge, where it is 5½ feet thick. At a short distance beneath this appear the Seral sandstones. Both of these coals, with their accompanying rocks, are far below the water-level in the immediate neighbourhood of Ligonier town, and emerge to the day only on the two sides of the basin.

The large Pittsburg Coal occurs on many farms along the central part of the valley, having its E. and W. outcrops along the slopes of a range of high narrow hills occupying the middle of the trough. It varies in thickness from 7 to 10 feet. The coal is jet black, of a brilliant lustre, and comparatively free from sulphuret of iron and from slate.

It is of a firm texture, though it affects, to a partial extent, that columnar form so prevalent in many of the coal-beds in the basins near the Alleghany Mountain. At Giesy's it is lifted in long columnar pieces, but at Kieffer's and other places it does not show this structure.

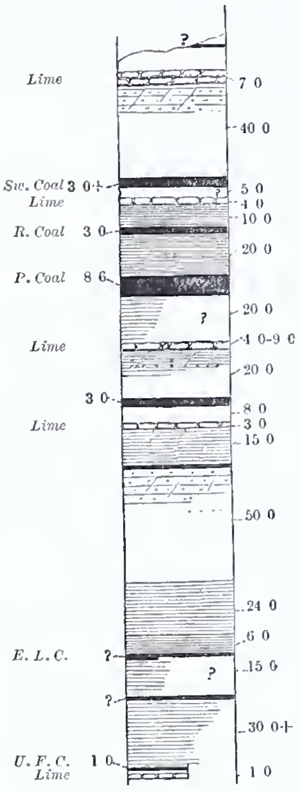


Fig. 565.—Ligonier.

The Brookville Coal, worked near the foot of Chestnut Ridge, after dipping under the valley, emerged on the other side of it, between Laughlintown and Laurel Hill, where its outcrop is indicated by a smut immediately above the upper beds of the Seral conglomerate. It is there overlaid by several other seams occupying the position of the lower beds seen in our previous sections. Thus above it the Ferriferous Coal-bed; 1½ feet thick, is seen, accompanied by a limestone. Next in the order ascending are two thin adjacent bands, the representatives probably of the Kittanning Coal, while higher up occurs a bed, which is here 3 feet thick, and accompanied by a considerable amount of iron ore.

At Ross furnace, in the same belt of strata, but farther to the N. by 6 miles, the Brookville Coal-bed was opened by us, and ascertained to be 4½ feet thick, though it had lain neglected, under an erroneous belief that it was of very insignificant size. A knowledge of the stratification led to the apprehension that some error had been committed in the original opening of the bed, and the result of a re-examination furnished a striking illustration of the value of systematic investigation even in a country the resources of which may be supposed to be already developed.

A carefully-compiled section, elaborately made from observations in a great variety of places, shows that the only valuable material included within the first or uppermost 150 feet of strata in the central hills of the valley, is a single band of limestone, about 1½ feet thick, while the only workable coal-seam within the space is a high bed, probably the first beneath the Pittsburg Coal, near the top of a hill in the very middle of the basin. Below this barren group of rocks, but only at the sides of the valley, occur the lower coal-seams and a limestone. Thus the Upper Freeport Coal-bed shows itself along the valley of Four-mile Run, and a little farther W., immediately at the base of Chestnut Ridge. It is opened at the bridge over the stream, on the Greensburg Road, a mile W. of Four-mile Run, where it is 3 feet 1 inch thick. This bed corresponds in position with that opened 6 miles S.S.W. from Ligonier, though the latter bed is only 1 foot 1 inch in thickness. So remarkable a declension in the size of the bed in so short a distance in this direction, is the only circumstance which suggests any doubt in respect to the identity of the coal of the two places. A band of limestone accompanies the coal at each locality. Indications of a large bed of coarse calcareous iron-ore occur in immediate connection with the limestone at the place mentioned on the Greensburg Road.

On Chestnut Ridge, near an old furnace on Jacob's Creek, 3 miles S.W. of Harman's, the same coal-bed has been opened, and shows a thickness exceeding 4 feet. A band of cannel coal, 6 inches thick, traverses the seam about 18 inches from the roof both here and at the opening just previously mentioned, serving, if other evidence were wanting, to identify the bed. Its underlying limestone and attendant iron-ore were also found within 4 or 6 feet of the coal. The limestone measured 1 foot, and the kidney ore over it amounted to from 2 to 5 inches in total thickness.

The Kittanning Coal is separated by about 40 feet of sandstone from the Upper Freeport Coal, and by 35 feet of shale from the Ferriferous Coal, which is here, like the Kittanning Coal, 2 feet thick. The separating shales contain a solid band of iron ore of excellent quality, varying in thickness from 5 to 8 inches, besides a considerable amount of ore in detached flattened balls. These things occur at Harman's, up Four-mile Run, above the mill which is at the crossing of the Greensburg Road. The spot appears to be important on account of the abundance and good quality of the ore, though the immediately adjoining coal-beds are scarcely of sufficient thickness to be available for the manufacture of iron at this place, the thicker workable Upper Freeport Coal, with its companion, the limestone, lying higher up in the same hill. A heavy bed of conglomerate underlies the Ferriferous Coal and Limestone.

The following section was made upon Four-mile Run, 5 miles above its mouth, constructed upon the hypothesis that Mr Nelson's coal-bed is the same found upon the road leading from the mill to Greensburg.

Top of Hill, 30 feet; Coal (?) terrace; Shales, 10 feet. Limestone of Barren Measures, 1½ feet; Interval, 8 feet. *Coal Smut*, 6 inches; Roof and floor, grey-streaked Sandstone (this is probably the coal swept away from the summit of the hill at the head of the other section, leaving it flat, and sloping at an angle of 7° to the E.S.E.) Sandstone, &c., 50 feet. Coal Smut; Interval, 30 feet; Black Slate, 8 + feet (containing 1 inch of coal, and underlaid by an argillaceous conglomerate, hard when dug, but soft on exposure); Shales, 6 + feet. *Nelson's Coal*, 13 inches; Yellow Clay; Interval, 4 to 10 feet. *Limestone.*

Another section, made at Mr Nelson's, 4 miles distant from that now given, reads thus:—

Olive Shale, 20 feet. Black Slate, 15 feet. *Coal* (?); Interval, 10 feet. *Coal* (?); Interval, 20 feet. Olive Shales, 10 feet. Fire-clay, 6 inches. *Coal*, 3 feet 1 inch. Fire-clay, 3 feet; Interval, 8 feet. Limestone (?) (continued at Mr Herman's, on Four-mile Run), conglomeritic Sandstone, 20 feet exposed, perhaps 50 feet in all; Shales, 30 feet; Black Slate, 10 feet. *Coal*, said to be 2 feet; Black Slate, 7 feet. Shales, very ferriferous, 14 feet, containing perhaps 1½ feet of ore; Iron ore, black carbonate, 5 to 8 inches thick; Shale, compact, 3½ feet; Sandstone, Shale, &c., 8 + feet. *Coal*, 2 feet, good at water-level. Seral conglomerate.

Eastward from the old furnace of Jacob's Creek occur the Ferriferous and Kittanning coal-beds, with their interposed iron-ore. Here they are only 20 feet apart, and show a corresponding reduction of thickness, the Ferriferous Coal-bed measuring but 1 foot, and the Kittanning Bed, 1½ feet. In the interval we find 6 inches of good iron-ore embraced within 4 feet of shale.

Near the above spot the red Umbral shale shows its limestone cropping out in a stratum 15 feet in thickness. The iron ore near the top of the formation was formerly procured for the furnace. It lies in several bands, whose aggregate thickness is about 8 inches.

The topographical features of the part of the basin we have been describing are somewhat peculiar, owing to the prevalence of soft shales in that portion of the series occupied by the hills of the central belt of the valley. The summits are often quite plain, though gently sloping in conformity with the gentle dip of the strata.

South as well as North of the Somerset and Mount Pleasant Road, the Barren Measures fill the middle of the basin.

The Upper Freeport Coal and its limestone certainly exist at the base of the hills, and perhaps the next inferior Lower Freeport Coal. These are the only available strata in all the central region at the head-waters of Indian Creek.

Passing Southward down the tributaries of Indian Creek, we follow this stream for 8 or 10 miles through the Coal-measures, descending in the stratification until we reach Fayette furnace at the mouth of Laurel Run, where the stream flows over rocks that may be referred either to the upper part of the Seral conglomerate, or the lower portion of the Coal-measures; for the Brookville Coal (here 100 feet beneath the creek) may be assigned as well to the former as to the latter. Continuing down the creek, which enters lower and lower strata in its course, the underlying Brookville (?) Coal-bed at length appears about 2 miles below St John's furnace, where it is embraced among massive sandstones, which form a series of steps at their outcrop along the channel of the creek nearly the whole way from a mile above the furnace to the mouth of the stream. We may consider the main body of Seral conglomerate to commence below the coal-bed, and to embrace all the rocks thence to near the mouth of the creek, where the stream at last reaches the Umbral red shales, exposing them in a thickness of 50 feet resting upon their well-marked calcareous sandstone at the water-level. As the rocks here dip gently E. towards the middle of the basin, we find these Umbral beds disappearing below the Youghiogheny as we ascend it in the same direction, the neighbouring bluffs showing all the way at their base vast bodies of debris in the form of broken blocks of sandstone and conglomerate, derived from the cliffs above, where the Seral conglomerate rises nearly perpendicularly 200 feet from the stream. Regarding the Seral conglomerate as terminating at the first coal-seam, the total thickness of the formation will be about 150 feet; but if we make it to embrace the coal and the over-resting conglomerate and sandstone, the whole will measure about 250 feet. Ascending the river, the Umbral shales are out of reach until we get about 2 miles above the Ohiopile Falls, where they emerge with a tolerably steep Western dip, and are followed, as we approach the gap of the mountain, by the Vespertine Sandstones, and finally, at the axis of the ridge, by those of the Vergent series.

The sections designed to exhibit the stratification in this region were unavoidably meagre, though data enough were collected to establish an accordance among themselves, and between them and the corresponding parts of a more complete section obtained in the neighbourhood of Fayette furnace.—(See Fig. 566.)

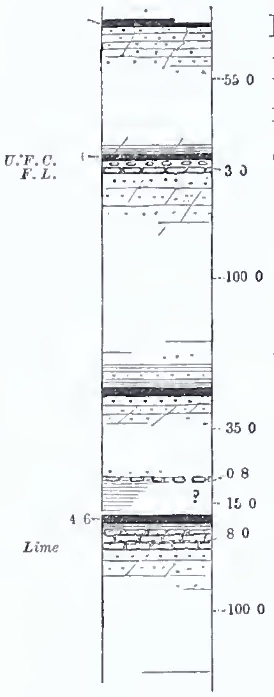


FIG. 566.—Indian Creek.

The largest coal-bed in this part of the valley is the Ferriferous Coal, which, near the furnace, yields 3½ feet of good coal, and an extra foot of an inferior kind. It has also been exposed, at intervals, for several hundred feet, by the erosive action of the stream along Indian Creek just above the mouth of Laurel Run; and was once worked at this place by stripping it at its outcrop. At both of the above localities it underlies a bed of brown shale. The coal may be seen cropping out in a deep ravine to the W. of Indian Creek, crossed by the turnpike leading to Connellsville. It was once mined by stripping at St John's furnace, where its elevation above the stream is about 80 feet.

The limestone accompanying this coal appears where the turnpike crosses Indian Creek, in a bed 8 feet thick. About 15 feet above the coal lies a band of iron ore 8 inches thick.

The coal-seam, previously stated to be 100 feet lower in the series, was passed in boring a salt-well near the furnace. Its thickness in the well has been stated to us at one foot, agreeing with its dimensions at its outcrop in the creek's bed, 2 miles below St John's furnace. This coal is of excellent quality.

Fifty feet above the Ferriferous Coal-bed lies the Kittanning Coal, once opened where the turnpike ascends the first hill W. of Indian Creek, and stated to be 3 feet thick, but of indifferent quality.

About 100 feet above this, a band of light-coloured pure limestone has been quarried, the thickness of which could not be ascertained from the falling in of the earth. A bed of coal overlies it within a few feet, yielding, it is stated, 3 feet of good coal. Strata deemed to be the same were met with 4 miles farther S., where the coal is in two bands, separated by nearly 4 feet of fire-clay, the upper band showing 3 feet of coal containing no impurity but sulphuret of iron, and the lower band 1½ feet of equally good quality. A calcareous spring, indicating the outcrop of the limestone, issues about 15 feet below the outcrop of the coal. About 40 feet above the coal-bed occurs a bench, which suggests the presence of another seam. Being unable to procure any extensive continuous section of the strata in this vicinity, we are in some doubt as to which part of the Coal-measures we are to refer the first-mentioned seam with its limestone, for we may regard it as either the Freeport or the Ferriferous bed of the series. Appearances incline us to refer it to the former.

At Lennard's, one mile N. of Bear Run, appears a band of the Ferriferous Limestone, though the coal itself has not yet been seen here. Fifty feet higher in the hill is an outcrop crossing the road, which appears to belong to a large bed. Westward of Lennard's, towards the river, two lower coal-seams have been opened on a small run; the uppermost being 1½ feet thick, and the undermost, 100 feet farther down, being 2 feet thick. No limestone has yet been recognised accompanying the first of these coals.

To return to the section at Fayette furnace, we find from 50 to 60 feet above the Upper Freeport Coal and its limestone, a well-marked bench, containing probably the highest seam which has resisted the denuding action of the waters in this part of the valley.

On Bear Run, 3 miles N. of the Ohiopile Falls, and one mile from the river by the course of the run, a coal-bed has been opened, yielding 3 feet of very pure coal. It overlies a mass of sandstone, this rock constituting the principal material between this level and that of the river below. It was impossible to decide upon the precise position in the series held by this bed, though everything, except the absence of a band of limestone, suggests its reference to the Ferriferous Coal-seam. It is regarded as the purest coal in this section of the valley. A very irregular coal-seam occurs 30 feet down, between the sandstone: it varies from an inch to a foot in thickness, and probably corresponds with a very irregular bed observed at the Ohiopile Falls, and again on Maiden Creek; at which latter place it rests beneath 20 feet of sandstone, and is 2 feet thick, having the appearance of having been crushed.

Signs of coal occur near the head of Bear Run, where the hills rise to an elevation of nearly 250 feet above the position occupied by the Seral conglomerate. Near their summits we find a coal-smut, indicating a large bed, probably the same with that already noticed as appearing in the road at Lennard's. In the Seral conglomerate occurs here a bed of coal 2 feet thick.

That part of the valley embraced between the Youghiogheny and the S. line of the State has yielded us less satisfactory data for a description of its geology than any district farther North. The season appropriated to it being far advanced, and the country requiring a more leisurely examination to reveal its obscure stratification than we were able to afford, little was accomplished beyond what amounted to a reconnaissance of its topography, and the identification of a few of its beds.

A seam of coal was formerly opened and mined to a small extent on the first stream which enters the river from the W. below Cucumber Run. It is 4 feet and a few inches thick, including 5 inches of slate near the top. Lying on the banks of a stream having little fall, and in a neighbourhood deficient in exposures of the strata, it was impossible to settle its position in the series, though the evidence which would refer it to one of the lower beds preponderates. Did any evidences of limestone accompany it, we should regard it as the Ferriferous Coal; yet this rock being elsewhere sometimes several feet below its coal, it may exist here under the level of the run. Though no other coal-bed has been discovered in this neighbourhood S.W. of the falls, the great height of the hills, and the occurrence of several benches, imply the existence of at least four or five seams in all.

Near the middle of the valley, and half a mile N. of the National Road, coal occurs in the lowest grounds. Fragments of conglomerate abounding near it, induce us to refer it to the Ferriferous Coal-bed. The seam is 3 feet thick, parted in the middle by an inch of slate; it yields a fuel well adapted to the purposes of the blacksmith. It is worked by stripping only. The strata here are level. About 30 feet above this, in an adjoining hill, is seen the smut of another coal-seam (Kittanning Coal ?), which corresponds very well in position with the bed at Smythfield in the basin E. of Laurel Hill. Another bench, showing black coal-slate (Lower Freeport Coal ?), appears 25 feet above this. These three are all the coal-beds thought to exist in this neighbourhood.

A fourth of a mile S. of the National Road, and one mile E. of the former place, a coal-bed (Kittanning Coal ?), corresponding in character with the Smythfield Seam, is worked at its outcrop. The bed contains, first, a layer of coal 2 feet thick, resting on one foot of good fire-clay, and this is underlaid by 15 inches of coal, which also reposes on good fire-clay. The coal, otherwise pure, is somewhat sulphurous. Twenty-five feet above this may be noticed another coal-bench (Lower Freeport Coal ?)

At Chalk Hill on the National Road, not far from Stewart's furnace, there occurs a poor bed of slaty coal, overlaid by a heavy bed of olive shale; it is 1 foot 6 inches thick. A well sunk 50 feet below this coal reached no other bed, nor did it meet the coarse sandstone of the Seral conglomerate, which crops out within less than a mile W. of Chalk Hill, towards Chestnut Ridge, here erroneously called Laurel Hill. Higher up the mountain the calcareous sandstone near the base of the Vespertine series displays itself; it is used as a road stone, for which it is well suited by its toughness.

The lowest seam of coal along the W. margin of the basin might, I conceive, be easily detected by following the indications of the rocks exposed along the National Turnpike. Its discovery here would prove of some utility.

CHAPTER XXX.

OF THE THIN GROUP OF COAL STRATA BETWEEN THE UMBRAL RED SHALE AND THE MAIN SERAL CONGLOMERATE, IN SOMERSET AND FAYETTE COUNTIES.

In describing the strata in the neighbourhood of Turkey Foot, in the basin E. of Laurel Hill, we made mention of a thin group of coal-bearing rocks, having no connection with the main body of the Coal-measures, but holding a position between the upper layers of the Umbral and the lower rocks of the Seral series. These earlier-formed carboniferous strata, gradually developing themselves in our progress to the S.W., do not show themselves conspicuously in the basin W. of Laurel Hill until we reach the district S. of the Youghiogheny, corresponding to the Turkey Foot country on the opposite side of the mountain. Near Stewart's furnace they contain a seam of excellent coal 4 feet in thickness. It lies entirely below the coarse Seral conglomerate, and 20 feet below the band of iron ore which usually marks the upper limit of the Umbral red shale. The ore occurs in a brown shale, so that it may be considered as appertaining to the Coal-measures, which thus form, as it were, a subordinate part of the Umbral red-shale formation. This ore occurs in four separate bands, two of which, within 3 feet of each other, are near enough to be worked together. The upper band is less than 1 inch in thickness, while the lower varies from 1½ to 3 inches. These were the most productive layers known here, until others a little thicker were discovered in the same formation N. of the National Road, and 4 miles from the furnace. In the newer locality the ore lies in two adjacent layers, equivalent in all to a thickness of about 8 inches ; its quality is very good. The same ore, at the top of the red shale, was formerly worked on the Clay Turnpike on Chestnut Ridge near Connellsville, and is said to have proved abundant and good.

Valuable bands of iron ore occupying a similar position have already been exhibited, in a section representing the stratification at the gap of the Cheat River through South Laurel Hill (Chestnut Ridge).

Iron Furnaces.—The following are the iron furnaces W. of the Alleghany Mountain, and E. of Chestnut Ridge, which, in 1854, were engaged in the smelting of iron :—

Four at Johnstown—Cambria Iron Company. One at Johnstown—Ray and Mathews. One, Conemaugh Furnace, in Laurel Hill Gap—Ray and Mathews. One, Indiana Furnace, ½ mile N. of Canal—Baker. Two on Black Lick Creek, 3 miles N. of Canal—Buena Vista Furnace and Cambria Iron Companies. One, Cambria Furnace, 3½ miles N.W. of Johnstown—Cambria Iron Company. Two, 3 miles S. of Johnstown, on Mill and Ben's creeks—Cambria Iron Company. One, Laurel Hill Furnace, 6 miles S.W. of Conemaugh—Royer and McAllister. One, Hall and Company's Furnace, 10 miles S. of last. Two, Hall and Company's, and Mathial and Company's, 10 miles farther S. One, Shade Furnace, 16 miles S.E. of Johnstown.

PART III.

MESOZOIC RED SANDSTONE SERIES.

INTRODUCTORY CHAPTER.

In the triple subdivision of the strata of Pennsylvania, the Mesozoic Red Sandstone, constituting the uppermost or latest system, presents itself for description after the Palæozoic formations: it will form the subject of the present subdivision of my work. Though a somewhat extensive stratum, it will not demand a very elaborate delineation, for the formation is characterised by no great variety of composition, possesses extreme simplicity of structure, has a very limited group of minerals, and is, moreover, almost wholly destitute of organic remains. I shall describe, first, the geographical limits, composition, local features, and mineral contents of the formation; in the next place, the igneous rocks of the district, and the changes they have caused in the stratified masses in contact with them; and shall close with an investigation of the geological age of the stratum, and of its origin, or the conditions under which it was deposited. The name *Mesozoic Red Sandstone*, by which I here propose to designate this deposit, is given to it in allusion to the geological age in which it was produced, both its organic remains and its position among the other systems of strata distinctly indicating it to have originated early in the so-called Mesozoic period, or the middle ages of extinct or fossil life. As a term, it is less theoretical and more descriptive than that of New Red Sandstone, the title often conferred upon it by geologists; it seems called for, likewise, as recognising the valuable nomenclature recently proposed for the fossiliferous rocks by Professor Phillips and other British geologists.

Geographical Limits of the Mesozoic Red Sandstone.—The entire area of this formation, one portion of which crosses Pennsylvania, is very great. It commences at the W. bank of the Hudson River, in a broad belt extending from the Bay of New York to the base of the first ridges of the Highlands, and is bounded on the N.W. by this chain and its continuation. South-westward it traverses New Jersey, Pennsylvania, Maryland, and, in a more interrupted manner, Virginia and a part of North Carolina, so that its total length is not less than 500 miles. Having a width in New Jersey of 20 miles between the Hudson and the Highlands, it crosses the Delaware into Pennsylvania with a breadth expanded to nearly 30 miles. It retains this until it approaches the Schuylkill, where it rapidly contracts, and maintains for the remainder of its course through Berks, Lancaster, Lebanon, Dauphin, York, and Adams counties, the diminished breadth of about 10 miles between the Schuylkill and Susquehanna, and of 15 between this latter river and the Maryland State line.

The S. margin of the formation crosses the Delaware River about 1½ miles above the town of Trenton, runs nearly W. to the Schuylkill, which it passes about 2 miles S. of Norristown. It advances by Valley Forge and Kimberton to French Creek, the course of which it follows nearly to the county line of Chester. It passes about half a mile to the N. of Morgantown, Churchtown, and Hinkleton, and goes through Millport to Buchanan's Run, when it suddenly folds back and runs towards the N.E., through Ephratah to Reamstown. From the last point it sweeps in a regular curve, first towards the N.W. and afterwards the S.W., crossing the turnpike at Middle Creek. Reaching Hammer Creek, it descends along the course of this stream to Erb's mill, where it turns again W., passing about a mile to the N. of Litiz, and reaches in the same course Manheim. Here it advances once more towards the E., which direction it pursues as far as Buchanan's Run, where, however, it again turns W., continuing in that course uninterruptedly to Springfield, at which place it makes another short flexure, but soon resumes its W. range, passing 1½ miles S. of Elizabethtown, and thence nearly in a straight line S.W. to Bainbridge on the Susquehanna.

Crossing the Susquehanna, the S. edge of the formation leaves the W. bank of the river about one mile above the little village of New Holland, nearly opposite to Bainbridge, and maintaining a direction very nearly S.W., the line extends to the N. base of the Pigeon Hills, passing about 2½ miles N.W. of the town of York, and crossing the York and Gettysburg Road, 9 miles W. of the first-named place. It now ranges along the N.W. foot of the Pigeon Hills, at the W. extremity of which it deflects somewhat more towards the S., and, passing one mile to the W. of Littlestown (Petersburg), it reaches the Maryland line near Arnold's mill on Piny Creek.

From the Delaware River at Trenton to the vicinity of Willow Grove the red sandstone overlaps the gneiss; between that point and the neighbourhood of Valley Forge it is in contact with the altered Primal and Auroral rocks, but chiefly with the limestone of the valley. From Valley Creek to the Warwick Iron-mine, near the head of French Creek, the S. margin again covers the gneiss; beyond this latter locality, for 3 miles to the edge of Chester County, it conceals the Primal sandstone and slate of the Welsh Mountain; and thence through the whole length of Lancaster County to the Susquehanna it is everywhere in junction with the Auroral limestone.

Crossing the Susquehanna, this S. or rather S.E. border overlaps first the Auroral limestone for a mile or more from the river, it then covers the Primal rocks of the Chiques anticlinal belt N.W. of the Codorus for 2 or 3 miles farther; thence to the foot of the Pigeon Hills it is again in contact with the limestone, and along the foot of these hills with the Primal slate. From their S.W. termination nearly to the Maryland line it overlaps once more the limestone, and at the State line rests again upon the Metamorphic Primal slate.

The N. border of this Red Sandstone formation, crossing the Delaware near Durham, will, if traced W., be found to pass about one mile S. of Springtown, and one mile N. of Cooperstown to the Hosacock Creek, where the road crosses it in Upper Milford Township. It then runs a little to the S. of the Mount Pleasant Iron-mines, passes Boyerstown, crosses the Perkiomen one mile S. of the Black Bear Tavern, and meets the Schuylkill about 2 miles S. of the town of Reading. From this latter point the N. edge of the sandstone stratum extends, with a slight undulation, in a nearly W. direction to the S.W. end of Millbaugh Hill, overlapping first the limestone of the

Kittatinny Valley, then gnessic rocks, and finally the Primal white sandstone of the hill. From Millbaugh Hill its range is a little S. of W., through Shaefferstown, past the Cornwall Iron-works, and thence along the turnpike to Campbelltown, from which spot it takes a nearly straight course to Highspire on the Susquehanna. Between Millbaugh Hill and the Susquehanna, the red-sandstone formation lies everywhere in contact with the Auroral limestone of the Kittatinny Valley.

Passing the Susquehanna about 1½ miles below the mouth of Yellow Breeches Creek, the N. or N.W. edge of the formation is in contact with the Auroral limestone as far as the E. extremity of the South Mountain north of Dillsburg. From Dillsburg to the Maryland State line it is everywhere bounded by the base of the South Mountain, the line of contact of this group, and the Primal rocks of that chain, curving gently Southward, and passing by the little villages of Middletown, Cashtown, and Fairfield, and meeting the State line a little W. of Emmettsburg.

Composition of the Mesozoic Red Sandstone.—The predominant portion of this formation consists of reddish-brown shale and argillaceous sandstone in intimate alternations. In some parts of the mass, the argillaceous matter is in such excess that certain beds are little else than a homogeneous consolidated clay, with the laminæ of deposition extremely indistinct. Elsewhere there is such a superabundance of silicious sand in some of the strata as to constitute these true arenaceous sandstones; but this last-named variety of the rock usually includes a sufficient proportion of the red ferruginous clay to possess some shade of reddish brown, more or less pale or deep as the sandy particles more or less prevail. Occasionally, though rarely, there occurs a nearly white stratum, composed almost exclusively of rather weakly cohering sand. It is in the inferior and upper portions of the formation, or near its N. and S. margins, that we meet, for the most part, with the more distinctly arenaceous strata. In these portions of the belt, true sandstones, well adapted to architectural uses, are not uncommon; and in some localities, as on the Schuylkill and on the Delaware, but especially in New Jersey, extensive quarries are wrought, supplying a very beautiful building-material to the cities of Philadelphia and New York. On the New York side of the belt there are also red silicious coarse grits or conglomerates, well adapted to withstand heat, and therefore extensively employed as hearthstones for iron furnaces. In the central and upper parts of the deposit we not unfrequently meet with dark-grey and blue shales, containing much carbonaceous matter in a partially pulverulent state, and here and there a chunk of true compact *Lignite*, more or less bituminous, but retaining distinctly the fibrous structure of the wood from which it has been derived. This lignite is even occasionally in continuous layers of 2 or 3 inches thickness, extending for several yards. Approximating to the features of genuine coal, these little seams are a fertile source of delusive hope among those who are ignorant of the geological relations of our strata.

Besides the great body of red shale and sandstone thus characterised, the formation includes near its upper and lower, or N. and S. limits, two other subdivisions which claim a special description: these are coarse conglomerates, very heterogeneous in composition, and interrupted in their line of outcrop. In the E. part of the belt, and especially near the Delaware, the base of the whole formation is a mass of coarse pinkish and greyish sandstones, composed of rather angular fragments of quartz, felspar, and a little mica, the constituents of the neighbouring gneissic strata. These beds graduate upward into the soft red argillaceous sandstones; but in the vicinity of the Susquehanna, and at intervals along the S.E. edge of the belt in York and

Adams counties, a conglomerate of a very different quality holds the same position in the formation. It consists of pebbles of the adjacent older formations, especially the Auroral limestone and Primal sandstone, with some quartz, all cemented in an exceedingly irregular manner in a paste of the brownish red clay or shale. The composition of this conglomerate varies greatly, being influenced by the nature of the contiguous older rocks from which its coarse materials have been derived. These pebbles are of all dimensions up to a diameter of 5 or 6 inches.

Another very similar calcareous conglomerate to that which forms the base of the formation W. of the Susquehanna, constitutes in several neighbourhoods the upper or terminal stratum. This bed is so well characterised, and so little involved in the general red-sandstone deposit which it caps, that it is entitled to be regarded as a distinct sub-formation, the result of a special train of physical actions ; it overlies the red shale along its N.W. margin, not in a continuous belt, but in several long narrow patches. It is an extremely heterogeneous rock, its pebbles, which are more or less water-worn and abraded by mutual rubbing, and which are of all sizes, from that of a grain of corn to that of a man's head, consisting promiscuously of all the materials of the neighbouring strata imbedded in a cement of the common red shale. In certain localities along the base of the gneissic hills between the Delaware and Schuylkill, a part of the pebbles are referable to the adjacent gneiss and Primal sandstone ; and this is also the case at the foot of South Mountain in York and Adams counties ; but the prevailing mixture is one containing a large proportion of pebbles of the Auroral limestone. Where the pebbles are for the most part from this rock, the cementing red clay is partially calcareous from infiltration ; in these instances the rock is susceptible of being readily quarried and dressed, and when polished forms a rather pleasing and singularly variegated brecciated marble. Of this character is the Potomac marble, so called, of which the columns in the late Hall of Representatives at Washington city are interesting specimens.

Of the Dip of the Strata.—Throughout this extensive red-sandstone belt, the dip of the strata is uniformly towards the N., or towards some point intermediate between N. and N.W. This is shown in all the general sections, from No. II. to No. X. The average inclination is from 15° to 20° ; perhaps it nowhere exceeds 25°, nor is it ever met with lower than 10° or 12°. This remarkable constancy in the direction and angle of the dip extends to both sides of the formation, and applies as well to the lower and upper conglomerates as to the main central body of red shale and sandstone. Throughout a breadth of nearly 30 miles, where the Delaware crosses the stratum, it preserves a uniform inclination of about 20°, although it is penetrated and overflowed in several places by masses of intrusive trap-rock. It is, indeed, a very interesting fact connected with the origin of this formation, that few, if any, of the very numerous intersecting trap-dykes, some of which are of enormous magnitude, appear to have exerted any influence upon the dip at the time of their eruption, unless, perhaps, they may have, in certain instances, added a little to its steepness, by compressing the horizontal area of the invaded mass. Scarcely in a single instance has the intrusion of the molten trap through the strata caused any sensible difference in the inclination of the opposite walls of the fissure ; and it is obvious that, if the dip of the sandstone were the result merely of the internal force which injected the trap, such a difference should appear, giving a S. dip on the S. side of the dyke. This singular regularity of dip in the transverse direction cannot, on the other hand, be due to a wide wave or flexure in the crust, for in the broadest parts of the belt we can perceive no gradation in the angle to mark the existence of such a curve ; nor will it meet the case to assume the whole tract to be but the N.W. slope of one vast anticlinal, whose summit and S. side may have been swept away—as the enormous length and irregular form of the belt at once precludes this hypothesis. We shall have to seek, then, for the origin of the dip and its constancy of feature in actions or conditions of the surface anterior to the appearance of the trap, and unconnected with any of those majestic movements of the crust from which the inclinations of all our other still older strata unquestionably proceeded. I shall, in a future page, return to the consideration of these actions and conditions, and endeavour to make it appear that this oblique bedding of the sandstone is an original feature impressed at the period of the deposition of each layer, and the necessary consequence of the peculiar state of the adjacent ancient topography, and of the currents carrying and precipitating these sediments.

Igneous Rocks of the Mesozoic Red Sandstone.—Numerous dykes of Trap, in its several varieties, occur in this great tract of the Mesozoic red sandstone, and it is a curious fact, difficult of explanation, that the chief portion of all the injections of this class are restricted, if not precisely to the present limits of this belt, at least to the more extended area originally occupied by it. This geological relationship of the trap to the sandstone is not merely a feature of the important portion of the formation embraced within the limits of Pennsylvania, but belongs to the entire length of the stratum from the Hudson to Virginia ; and what is still more striking, it obtains equally in the independent belt which fills the valley of the Connecticut. Nor is this association of the two rocks restricted to these two long narrow lines of Mesozoic depositions S.E. of the first great range of the Appalachian Chain ; it extends remarkably enough to the basin of Mesozoic Sandstone, for such it must be regarded, which occupies the South shore of the Bay of Fundy, in Nova Scotia. What the physical causes were, which, at the close of the Triassic period, confined the rupturing of the crust and the effusion of trappean matter to the comparatively narrow and local areas overspread by the Mesozoic red shale and their depositing waters, it is difficult, in the present state of geological dynamics, even to conjecture, and the present is not a fit opportunity for speculating upon a subject so purely theoretical.

The ordinary trap-rock of the Mesozoic belt of Pennsylvania—and the description is equally applicable to that of all the other districts above alluded to—is that variety which is known under the rather obscure name of Basalt, and which in its typical forms consists of an union of augite, felspar, and titaniferous iron, the first-named mineral predominating. In some dykes, however, the rock embraces much hornblende, replacing the augite. It is in such instances a true greenstone trap, but this is the less common variety of the two. It is of all degrees of relative fineness of crystallisation, from a coarse aggregate, such as we behold in some parts of the Conewago Hills, in Lancaster, in which the constituent minerals are very easily recognisable, to a very compact, almost homogeneous mass. It contains few extraneous minerals, and these are chiefly met with in the amygdaloidal varieties, near the borders of certain of the larger dykes, or more properly in immediate contact with the altered red shale, by the reaction of the trap upon which this amygdaloidal character has been acquired, and these minerals have been evolved, chiefly by segregation. They are principally *Epidote, Prehnite, Zeolite, Stilbite, Analcime, and Datholite.*

CHAPTER I.

DETAILED DESCRIPTION OF THE MEMBERS OF THE MESOZOIC SERIES.

RED SHALE AND SANDSTONE.

The very great general uniformity of the composition and contents of this extensive stratum renders it unnecessary to offer here a minute description of it under all its local exhibitions. It will be more expedient to pursue the course adopted in relation to certain other of the more monotonous portions of our geology, describing one or more transverse sections of the formation, where it is most diversified and fully developed, and introducing only such local details as are of specially practical or scientific value. A correct conception of the nature of the formation will be best conveyed by a description of its several features, as they may be seen in the vicinity of the Delaware River, where the belt has its greatest breadth. A reference to the general section No. II. will aid the reader in following this brief analysis.

Observing, as usual, the ascending order, I shall commence with the S. edge of the belt near Trenton, and treat successively of the several natural divisions of the formation as we reach them, proceeding Northward. Along the S. margin of the formation, near the Delaware, there is a well-marked subdivision, having a breadth of nearly 2 miles, and consisting of coarse reddish-grey quartz, with occasional strata of conglomeritic sandstone. This rock is exposed below Yardleyville; it is composed of small angular grains and imperfectly rounded pebbles of the minerals of the neighbouring gneissic rocks, the upturned edges of which it rests upon unconformably. The pebbles are chiefly quartz and felspar, those of the former mineral being in certain layers nearly an inch in diameter. Some of this quartz is slightly opalescent. Much of the felspar is in a state of partial decomposition, passing towards the condition of Kaolin, as indicated by its want of lustre, and its dull yellowish-white colour. A certain proportion of hornblende, and also a small amount of mica, likewise occur. Among these materials there is dispersed in minute nests or specks much yellow hydrated peroxide of iron: this substance, and the partially disintegrated felspar, weaken the cohesion of the rock, and much impair its value as an architectural stone. The bedding of the more arenaceous layers is not very regular, and there is generally an oblique lamination, the result of inclined deposition, a structure which materially injures the utility of this rock for many purposes. Interstratified with the beds of pure sandstone are many strata of a more argillaceous and browner sandstone, and innumerable layers of soft red shale. The lower member of the formation, as here described, is traceable under more or less distinctiveness of character, for many miles E. and W., in both directions, from the Delaware; it is visible near the Schuylkill, below Norristown, but is there extremely narrow. Between the Schuylkill and the Susquehanna it seems to be generally absent, having, perhaps, been swept away in the extensive denudation to which the S. border of the belt has been exposed in that quarter.

Above these rather heterogeneous rocks of the base of the formation there rests a series of beds of a somewhat different material, constituting a zone which, near the Delaware, is nearly 2 miles wide. In this division the predominant rock is a rather coarse-grained pinkish sandstone, composed of transparent quartzose sand, white specks of decomposing felspar, and occasional flat pebbles, or flakes of the compact red shale, or argillaceous red sandstone; but the silicious sand is the chief ingredient, and the cement uniting these materials is the red shale or clay. From the circumstance that no part of the formation has ever been deeply buried, either under a great mass of waters or beneath other strata, the cohesion of the particles in these rocks is somewhat feeble; nevertheless, the belt which I am now describing, furnishes altogether the best building-stone derived from the whole formation; it is quarried near Yardleyville, and in New Jersey, in a series of quarries near the canal; the stratification is for the most part regular, and the rock is easily quarried and wrought. Those varieties which possess a uniform reddish-grey colour should be preferred for architectural uses, since the quantity of disintegrating felspar present in much of the lighter and coarser pinkish sort, greatly impairs its cohesion and power of resisting the influence of the elements. This zone extends to the Schuylkill.

The next overlying division of the general stratum is much broader, extending from the Northern limit of that last described, to a point about 1 mile N. of the tract of Auroral limestone, near New Hope. This extensive mass includes all the more common varieties of the red shale, and red or brown argillaceous sandstone. All the forms of these rocks of every aspect, from the softest argillaceous shales, so homogeneous as scarcely to show the stratification, to hard silicious and micaceous sandstone, here abound in almost endless alternation. These strata, having a W.S.W. strike, range through the Southern half of Bucks and Montgomery counties, and appear in a broad belt N.E. of the Schuylkill. In the neighbourhood of the Delaware River this part of the formation is intersected by several enormous dykes of trap-rock, the heat imparted by which has caused an extensive alteration in the aspect and texture of the strata, and developed in certain localities some highly interesting phenomena of mineral segregation, the features of which will claim our attention in a future page.

Upon this group there lies a rather more diversified series of strata of alternating red sandstones and coarse yellowish conglomerates, subdivided by occasional thinner beds of the soft red shale. These coarser rocks much resemble those of the first-described division at the base of the formation. Some of the pebbles of quartz exceed half an inch in diameter; mingled among them are small flat fragments of red shale, evidently worn by attrition; many of the layers consist of a rather homogeneous coarse sandstone, and furnish a rock well adapted to some of the common purposes of architecture. This belt has a width of nearly one mile on the Pennsylvanian side of the Delaware: it crosses the river into New Jersey in the vicinity of Centre Bridge.

Passing the belt of conglomeritic sandstone, we again meet with the usual alternation of red shale and soft argillaceous red sandstone. These constitute a vast group occupying all the region between the belt just described and the calcareous conglomerate on the N. border of the formation. In the district of the Delaware these rocks are extensively altered by the temperature originally imparted to them by numerous dykes of trap-rock, and by much igneous rock which has not reached the surface, but of the proximity of which there exist the strongest indications. The partially-metamorphosed strata of the tract under consideration, which has its S. margin near the mouth of the Tohickon, are highly indurated and compact, have a prevailing dull-brown and purple colour, sometimes passing into dull-blue, and are moreover everywhere intersected by large joints cutting the beds into great rhombic blocks. Those portions which have experienced the greatest amount of igneous action have a semi-crystalline fracture, and when struck with a hammer give out a ringing sound. In the immediate vicinity of some of the large dykes where the alteration reaches its maximum, distinct mineral species have been developed in the shales by a well-known process of segregation, caused by extreme heat. The most common mineral thus elaborated from the union of the earthy particles of the sedimentary strata is Epidote, which here occurs in the form of spherical geodes or amygdals. The Nockamixon cliffs on the Delaware display these upper beds in all their features.

In the region of the Schuylkill, and through the whole tract between it and the Susquehanna, indeed as far as Maryland, the prevailing rocks are identical with these here referred to as forming the N. half of the formation of the Delaware. But the red shales and argillaceous red sandstones have not everywhere undergone the same amount of alteration from intrusive igneous matter. Except in the N. part of York County, there is no other neighbourhood in which the strata have suffered this general baking action to an extent at all approaching that discernible near the Delaware. A great number of small and insulated dykes of trap traverse the formation, and near the Susquehanna there are two or three of no inconsiderable dimensions ; but the changes induced by these injections rarely extend farther than a few hundred feet from the walls of the dykes, and in the greater number of instances are confined within narrower limits.

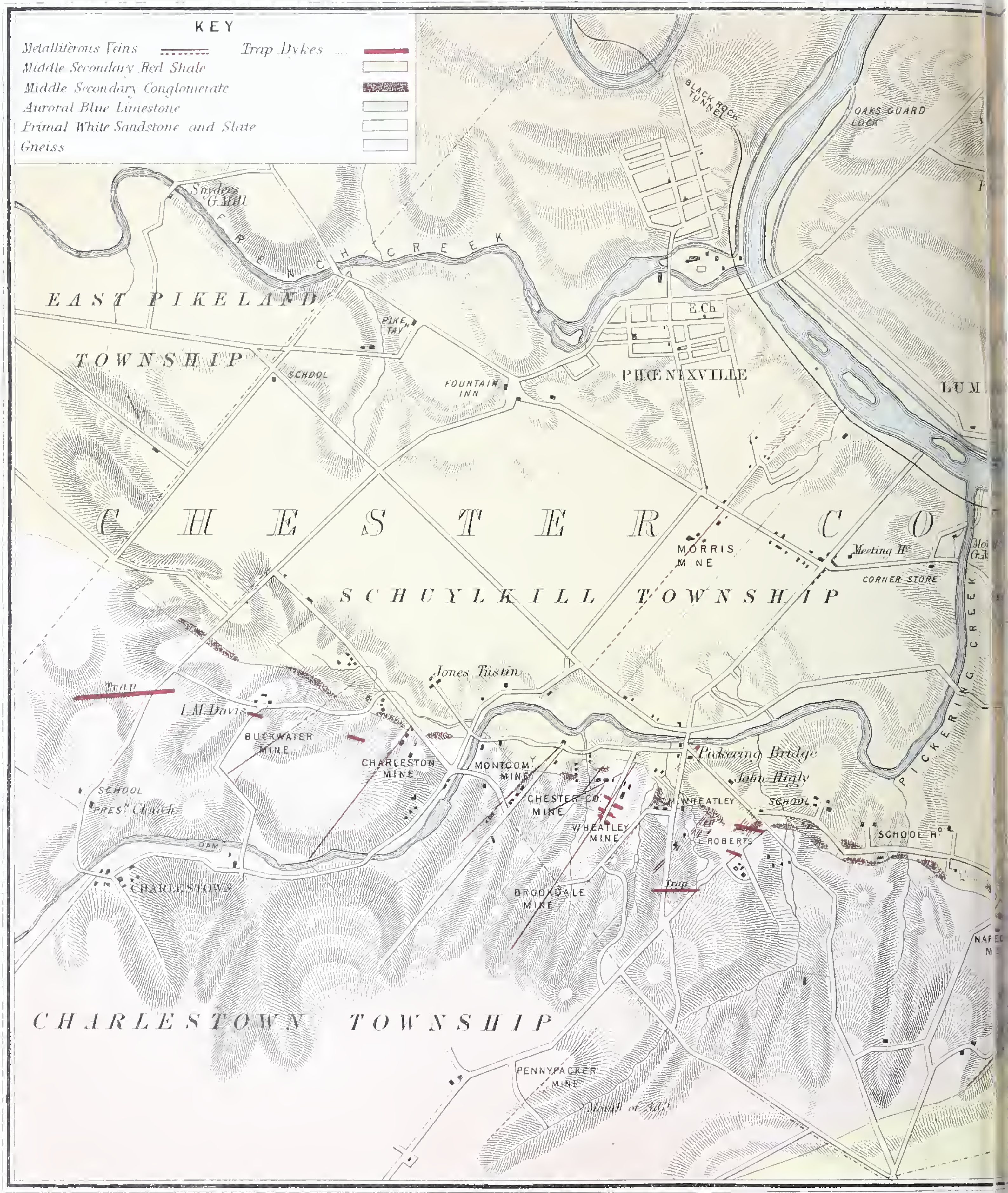
Throughout the district here described, the prevailing dip of the beds is about 18° or 20° to the N.N.W.

All along its N. border the formation contains, besides the ordinary red shales and red argillaceous sandstones, many strata of a coarse brown silicious sandstone, portions of which are often coarse enough to deserve the name of a conglomerate. These conglomeritic beds consist of little else than more or less angular grains of sand and small quartzose pebbles, cemented together by a very small amount of red shale or clay. It is difficult to trace these coarser beds very far, and it is certain that they are not to be regarded as great permanent members of the formation, but rather as local deposits of the extent of a few furlongs, or even a mile or two. Alternating with rocks derived from a finer class of sediments, they seem to indicate that the generally quiet movement of the waters was occasionally interrupted by sudden but not very widely extended currents, of sufficient velocity to sweep into this great estuary the heavier, coarser particles of its adjacent shores. Many of the silicious pebbles are fragments of the Primal white sandstone.

This coarse brown grit, or silicious conglomerate, has long been employed as a material for the hearths of iron furnaces, and in all cases where the fuel is charcoal, and the heat consequently not excessive, it bears the trial well. The hills W. of the Schuylkill have furnished hearthstones for many furnaces in the Eastern part of Pennsylvania for a long period. This rock, which is generally gathered from the surface, where it oftentimes is found in large detached blocks, is harder and coarser than the variety procured in Rockland County, New York, and which is known under the name of the Haverstraw Stone. In the application of anthracite coal to the smelting of iron, the more intense heat and greater force and volume of blast, compared with those used in the ordinary charcoal furnaces, cause a too rapid waste of the hearths constructed of this material. In this class of furnaces it is therefore not now employed.

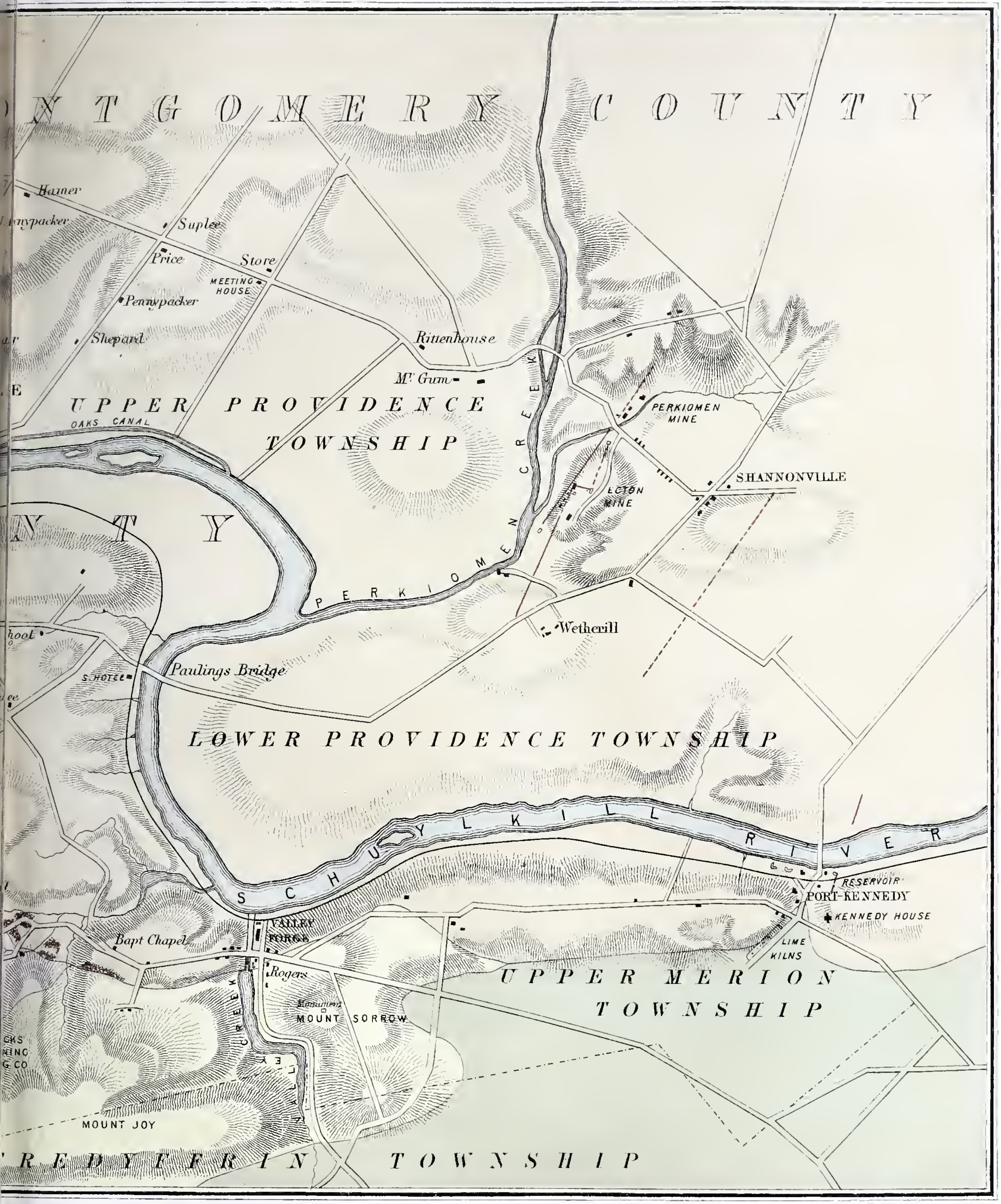
It is a general fact well worthy of notice, as bearing upon the question of the nature of the

MAP OF THE MINING DISTRICT OF



Engraved & Printed in Colours by

STER AND MONTGOMERY COUNTIES.



W. & A.K. Johnston, Edinburgh.

currents, and the condition of the surface at the origin of this Mesozoic formation, that not only these coarser grits, but indeed all the strata, viewed individually, are comparatively limited in their extent. We cannot, as in the case of many of the Palæozoic strata, trace any of the single layers over a wide area, but each bed appears to thin away at no great distance, and the whole mass, therefore, to be made up of narrow overlapping wedge-shaped strata. In this characteristic feature, the entire stratum bears a close resemblance to many estuary formations where we may witness, in the circumscribed extent and constant alternations of the smaller subdivisions of the deposit, the ever-shifting operation of river-currents, and of the still more inconstant tides.

On the Schuylkill, and in the belt of country between that river and the Susquehanna, the stratum presents very little departure from the type which it bears in all the middle and Northern portions of the section near the Delaware; the great mass of the formation being red shale and soft red sandstone, with occasional beds of more arenaceous grits and a few of silicious conglomerate. Perhaps there is, on the whole, a large proportion of grey felspathic sandstone in the series. This rock, some varieties of which seem well adapted to architectural uses, differs little in composition from the red and brown sandstones, except in the nature of the cement which holds together the granules of sand, this consisting, in the present case, of a whitish clay, apparently the product of decomposing felspar, and not of the common red shale. Some of these grey rocks imbed thin layers of bluish carbonaceous shale, with masses of lignite, and we not unfrequently find fragments of that substance, and of fibrous charcoal, imbedded in the sandstone itself. These facts indicate that such parts of the formation had probably an origin different from that of the red shales. Strata answering to the description here given are common in the vicinity of Litiz, Manheim, Mountjoy, and Elizabethtown, and they seem to constitute an almost continuous belt in this portion of the formation.

BOUNDARY OF THE MESOZOIC RED SANDSTONE IN THE CHESTER COUNTY LEAD-MINING DISTRICT.

Taking up the line of the red sandstone on the Schuylkill River at Port Kennedy, where a more than usually extensive denudation of its margin has cut it away, so that its edge touches the river, and tracing it W., we may follow it by the S.W. base of the ridge, running towards Valley Forge, the vale and meadow on the S. being in the Auroral limestone.—(See the Geological Map of the Mining District of Chester and Montgomery counties.)

Approaching the E. end of Mount Sorrow, or the N. hill near Valley Forge, the boundary extends a short distance to the W. of a cross road, and then suddenly swings back S. to recross that road, forming as it were a loop. It now sweeps round the low point of this hill, and takes its course once more steadily W., thus forming a sigmoid or double curve, as if the hill had jutted into the estuary of the red-sandstone waters, and deflected its shore line to make a little cove or bay behind it.

Tracing it over the N. flank of this hill, it passes to the N. of the Port Kennedy and Valley Forge Road, but on the W. descent recrosses this twice, the second time at the foot of the hill, near the Valley Forge Dam. From the W. abutment of the dam the line ascends a little slope, marking the junction of the Primal slates and red shale, parallel with the road leading Westward, and never more than 100 feet from it, until it gains the general level of the country, at the N. foot of the North Valley Ridge. It here passes about 250 feet S. of the Valley Forge Hotel, and is cut by the bed of the little brook W. of the Baptist Church, where the line is 700 feet S. of the main road. This point of intersection of the stream and the edge of the formation is an interesting spot, for it is just here that the Red Sandstone and the Primal slates diverge, and the gneiss rocks first appear at the surface, parting them as by the point of a wedge. The line, now taking a more undulating course, sweeps Westward and then N.W. over the hill dividing the little brook from the larger one of Vanderslice's machine-shop ; it crosses this latter stream a little below the factory, and then swings in a smilar manner to the S. of the next knoll, till it strikes and crosses the Main Pickering and Valley Forge Road. This it recrosses a few hundred feet farther on, or just W. of the abortive mine-shaft of the so-called "Napoleon Mine ;" thence it ranges once more nearly parallel with the road leading towards Pickering Creek, passing S. of Krause's Corner about 250 feet, and receding farther from the road, swings just S. of W. Miller's farmhouse by the margin of his meadow. Following the N. edge of the Meadow, it runs on Westward usually within 100 feet of the road, nearly touching the Friends' Meeting-house, and thus forward to the junction of the Pickering and Paoli Road, with Rapp's by-road. From this point we trace it through the fields to Wheatley's Gate, detecting it by the same chain of low summits which distinguish the outcrop of the conglomerate of the edge of the formation farther E. From Mr Wheatley's dwelling-house it may be pursued by the base of the knoll N.W. of his garden, and by the N. slope of the hill supporting the office of the Wheatley Lead Mine. Following the undulations of the ground, sweeping always Northward down the transverse ravines or little valleys, in obedience to the denudation on the outcrop, and swinging Southward round the higher-dividing summits and local water-sheds, the margin passes the Chester County Lead Mine, crosses the Brookdale Brook, and reascends Southward to nearly touch the stack of the smelting-works. Beyond this point it sweeps S. and N.E. through the fields next N. of the Montgomery Lead Mine, and touches the Pickering Creek Road just at Kinsey's mill. Here the outcrop takes another convex bend S. to touch the hill of the Charlestown Mine Shaft, and to range thence from near the office to the next ravine, along the W. bank of which it passes to the Buckwalter experimental mine-opening. Crossing the road, it next goes through the N.W. corner of J. Davis's field N.W. of his house. The edge of the formation is encountered on the road leading N.E. from Charlestown, at about half a mile S.W. of the Charlestown Mine Road.

In this vicinity, at the N. edge of a wood, there is a dyke of coarse felspathic granite just S. of the S. margin of the red sandstone.

Throughout the chief part of its distance from the first appearance of the gneiss near the Baptist Church to this Charlestown Road, the marginal beds of the red-sandstone formation are more or less conglomeritic, being composed of pebbles of quartz and sandstone of all degrees of size to the dimensions of hen's eggs, cemented by red shale or clay : this conglomeritic band is not, however, strictly continuous, being cut away by denudation for some stretches of a few hundred feet, and in others being too fine in its pebbles to attract attention as a conglomerate, or by its superior hardness to make any impression on the topography. It is between the E. commencement of the gneiss and the Black Horse Road at Wheatley's that the rock is developed most distinctly, but especially in the E. part of this space, and nowhere so conspicuously as between the Napoleon Mine and the Pennsylvania Mine Brook. In this E. part of the belt there are, in fact, two coarse massive beds of the conglomerate outcropping about 200 feet apart, almost identical in composition, and both capping a series of little summits or ridges. The lower of these forms, in fact, the little flat ridge along which the road leading by the Friends' Meeting-house passes. The two conglomerates evidently suggest two earthquake concussions, with a pause between them, early in the formation of the red-sandstone deposits. Their materials are manifestly derived from the adjoining older formations, especially from the Primal sandstones of the ridge just South. Much material of the adjacent gneiss, its granite veins inclusive, enters into the substance of all these lower beds of the red-shale series. It does not appear that the red-sandstone formation originally extended more than a very trivial distance S. of its present conglomeritic and sandstone margin, for no wide denudation in a region so irregular could have shaved off the whole Southern border so evenly as to stop over so long a line just at the base of this thin conglomerate. Undoubtedly this S. edge was greatly eroded and wasted in the district farther W., but not in this tract from Valley Forge Creek to the neighbourhood of Charlestown, where the S. barrier of hills was in fact too adjacent to give space for the waters of the formation to spread beyond the limits it there occupies.

Of the Red Shale and Sandstone in York and Adams Counties.—Having now exhibited in sufficient detail the composition of this formation in the tracts between the Delaware and Susquehanna, I proceed to sketch its features in the portion of the belt which is embraced between the latter river and the Maryland State line. The character of this portion will best appear by tracing a section along the W. bank of the Susquehanna.

Section along the West Side of the Susquehanna.—In the neighbourhood of the Susquehanna, the lowest member of the Mesozoic group is a calcareous conglomerate, consisting of large pebbles, chiefly of the Auroral limestone, cemented by a little calcareous red shale. This rock admits of an excellent polish, and has been wrought to a small extent as an ornamental marble. The belt crosses the river near the village of Bainbridge. On the W. side it is not well exposed. Overlying this rock is a coarse pebbly silicious conglomerate 80 or 100 feet thick, with some bands of red shale interposed. Above the conglomerate we find red shale alternating with red and grey sandstone, extending in very imperfect exposures, along the river-bank. It is chiefly of a grey colour, is micaceous, and in some places divides into very thin flat layers. Reposing on this rock we find a red shale.

At York Haven appears an altered rock S. of a trap ridge which lies immediately above the town. The trap-rocks of this ridge lie in large fallen masses for some distance along the river road; they are rather easily broken, and yield a good material for building: they are coarser and more crystalline in texture than those from the small dykes farther S.W. in the belt, and bear some resemblance to a sienite, having the hornblende and augite in distinct crystals.

Next above the trap is a hard altered slate or shale, which extends its ledges across the river, and forms the rock in the upper part of the "Conewago Falls." Above this occur fallen masses of trap from a spur of the ridge at York Haven, but no rock is seen in place for some distance. Near the mouth of Fishing Creek we have a red sandstone, which extends up the valley of the stream; it is highly valued as a building-stone. It was here that the red sandstone for the portico of the State Capitol at Harrisburg was obtained; it has also been much used in the construction of locks, bridges, &c. on the public works along the Susquehanna. Making good furnace-hearths where charcoal is used, it has been taken to a great distance for the purpose.

This rock is very abundant over a considerable part of the valley of Fishing Creek; but the purer sandstone is interstratified with much red shale in layers of varied thickness.

On the N. of Fishing Creek Valley there is another trap ridge, which abuts upon the river a little above Etter's Tavern. Near Etter's we perceive the influence of this trap on the shales and sandstone. Much of the altered sandstone has only its colour changed; but some of the altered shale, and an altered silicious conglomerate, contain *epidote* and micaceous oxide of iron. The epidote and micaceous oxide of iron are common in this neighbourhood; indeed, it seems to be a general condition both here and in other districts, that where the influence of the trap has been strongly exerted on the coarse sandstones and conglomerate, the result has been the production of epidote and micaceous oxide of iron, while the common red shale has been changed into a very tough compact bluish or purplish rock, varying in texture and colour in proportion to its contiguity to the trap, and sometimes containing rounded masses or small veins and strips of epidote.

About 300 yards above Etter's house we find the trap-rock in place on the river-bank, a little below which, and nearly in contact with it, appears the altered shale.

The trap-rock is exceedingly uniform in texture, not differing much from that of the ridge below, near York Haven.

The trap ridge above Etter's runs parallel with and near the river for about 4 miles, for which distance no rock is seen in place, the fallen masses covering the steep slope of the ridge to the very margin of the water. Near the mouth of March Creek the ridge leaves the river-shore, and stretches away N.W. towards Yellow Breeches Creek, below Lisburn. About the mouth of March Creek we have low alluvial ground for nearly a mile. The first visible rock on the river above the trap is a soft red sandstone; this is overlaid by red shale, which in its upper portion, near its contact with the South-east-dipping Matinal limestone, is somewhat calcareous, and evidently denotes the position of the upper calcareous conglomerate. The conglomerate in its true character is not found immediately at the river, but it is abundantly developed, as I shall presently show, along this line of outcrop farther Westward. Immediately N. of the last-mentioned calcareous red shale we meet the South-dipping limestone of the Cumberland Valley: this is about 1½ miles below the mouth of Yellow Breeches Creek, and nearly 5 miles below the Harrisburg Bridge. About 9 miles below Harrisburg there is an island in the river, called "Hill Island," from the circumstance of its having at its head a bold rocky hill, formed by a part of the trap ridge already noticed as reaching the W. shore of the river, a little above Etter's. S. of this trap we find the same range of altered rock, noticed near Etter's house as containing epidote and micaceous oxide of iron. Some specimens were found on the island, containing pisiform concretions of epidote, and others epidote and micaceous oxide of iron.

A very similar range of altered rock is found S. of the trap ridge which reaches the river at York Haven.

In the vicinity of the Susquehanna, and for 15 or 20 miles from it, much red sandstone is mixed with the red shale which overlies the lower conglomerate. This is particularly abundant in the neighbourhood of Strinestown, S. of the Conewago Creek, where large quantities of this rock are obtained for useful purposes, being taken to the river, and thence boated to different places for bridges, aqueduct locks, buildings, furnace-hearths, &c. Some of it is coarse, containing numerous pebbles, while the other strata are simple sandstone without pebbles. This rock forms the Conewago Hills marked on the State Map south of the Conewago Creek.

The N. branch of the Conewago Creek, opposite to and below Rosstown, flows chiefly in the hard blue altered shale, while on the S. side we generally find the red rocks not far from the stream.

About 3 miles South-westward from Rosstown, near the edge of the trap range, are some old diggings for iron ore, now long neglected. Some specimens were picked up among the rubbish which appeared to be chiefly a dark compact protoxide of iron, slightly magnetic.

The red-shale country about Berlin and Abbottstown is rather fertile and well cultivated ; but those portions of the red-shale belt S. of the trap, where the rocks are changed to a dark bluish or purplish colour, have usually a wet heavy soil, and are not so much esteemed for agricultural purposes. Two miles N. of Berlin we come to the altered bluish shale, and here, on a farm belonging to Mr Brown, traces of carbonate of copper are seen in the shale, and some excavations were made for the ore ten or twelve years ago, which are now filled up and neglected.

Westward from this, and about half a mile N.E. from Hampton, near the junction of the trap and the altered shale, there is what is called an old "*Silver Mine*," where some ignorant persons were deluded by the shining appearance of a micaceous oxide of iron into digging for silver. Some specimens found among the rubbish are considerably magnetic, and indicate that they might yield iron, if found in sufficient quantity.

Eastward and N.E. from Petersburg there is red shale ; and in this formation, at Gardner's, half a mile E. from the town, is a stratum of limestone in rather a novel position. It lies in the S. side of a little hill of red shale, dipping with that rock gently N.W., and is evidently an interposed stratum in the shale, which may be seen above it, while the slightly-altered shale of the little ridge S. of it must of course pass below it. The rock in the upper part of the stratum is rather loose, and the large interstices (which seem to be the effect of natural decomposition) are filled with red earth washed in from above ; the lower portion is more solid. A quarry has been partially opened here, and a kiln erected near it for burning this rock into lime ; but at the time of our survey it was not in operation. About 10 feet thickness of this stratum is apparent ; but its total depth is unknown.

The conglomerate seen at Robinett's is half a mile E. from Gardner's quarry ; but whether above or below it, or whether connected with it, we could not determine : the conglomerate is certainly in the lowest ground, and is also overlaid by red shale.

Another limestone is found from 1 to 1½ miles N. of Petersburg ; but this evidently belongs to the Auroral formation.

CHAPTER II.

LOWER CALCAREOUS CONGLOMERATE WEST OF THE SUSQUEHANNA.

We will now proceed to trace the range of the *Lower Calcareous Conglomerate,* forming the S. limit of the red-shale formation, from its position on the Susquehanna, a little above New Holland, S.W. to the Maryland line. It has been already said that it folds diagonally across the little limestone belt at New Holland, until, about a mile from the river, it conceals the whole of it, and reaches the range of silicious slate which runs W. from the mouth of the Codorus. This slate, like the limestone belt, is gradually covered by the invading red shale, until, about a mile W. of the York and Harrisburg Turnpike, it also disappears, and the lower portion of the shale series is found resting upon the limestone of York Valley. It may be proper to observe that the S. border of this red shale, or "Middle Secondary" region, is almost invariably marked by a line of gentle elevation above the country at its base, and this little elevation is called by the people in that region the "Red Hill," and in the country N. and N.W. of it the "Red Lands." The conglomerate, when present, usually lies at the base of Red Hill, and is seldom visible except when brought to the day by some ravine or artificial cutting. The main portion of Red Hill generally consists of the pebbly silicious conglomerate, or red sandstone, or, if neither of these is visible, of red shale.

Near Mr William Lerick's, about 2½ miles N.W. from York, the calcareous conglomerate appears in a cutting of the Carlisle Road, on the side of Red Hill. Some of the fragments abound in red micaceous oxide of iron. The same calcareous conglomerate is abundantly exposed in the bank near Lerick's distillery. Ascending a small stream W. of this spot, we meet above the conglomerate with a locality where many years ago excavations were made for coal, and it is said some carbonaceous matter was actually found. This digging, now almost obliterated, seems to have been made in a dark carbonaceous slate. Above and below this slate there occur two thin strata of limestone very similar in character, the upper one apparently 3 or 4 feet thick, and the lower one having only its upper surface exposed.

From this point at Lerick's, the South-eastern limit of the formation, ranging in a South-westwardly course, encroaches on the limestone range S. of it ; crosses the York and Gettysburg Turnpike a little E. of King's Tavern, 9 miles from York ; passes half a mile S. of King's, and meets the N. base of the Pigeon Hills, having entirely covered the branch of the limestone of York Valley, which passes on the N. side of these hills. Ranging Westward along the foot of the Pigeon Hills, it exposes the pebbly silicious conglomerate resting on the slate of the hills, and in some places extending a short distance up their N. slope. This pebbly conglomerate is finely exhibited near the road from Hanover to Abbottstown, about a mile from the latter place, but the *calcareous* conglomerate has not been observed along the N. side of the Pigeon Hills.

Passing by the W. termination of the Pigeon Hills, the lower margin of the formation rests again on limestone 100 or 150 feet N. of Adam Myer's lime quarries, near the Hanover and Carlisle Turnpike, 4 miles from Hanover. Thence passing near the Catholic Chapel, on Little Conewago, it bends rather more to the S., and ranges within a mile of Littlestown (Petersburg), reaching the Maryland line on the "Barren Slates," near Arnold's mill, having thus passed diagonally across the whole Southern belt of limestone. The calcareous conglomerate occurs in an altered condition near a small trap-dyke, 1 mile N. of Littlestown, at the base of the "Red Hill." It seems to consist of pebbles of white limestone, imbedded in a dark slaty paste. The most Southerly exposure of limestone is in a field 1 mile N. of the State line, and 1½ miles from Littlestown : it seems to be a variety of the conglomerate.

CHAPTER III.

UPPER CALCAREOUS CONGLOMERATE.

It has been already intimated that the Upper Calcareous Conglomerate does not form a continuous belt, but a succession of narrow insulated patches of no great length, at the S. base of the South Mountains; the longest of these is in York County.

The most Eastern mass of this formation is at Monroe, on the Delaware River, where it constitutes a bold hill, and abuts with a N.W. dip against highly-inclined and contorted beds of the Matinal limestone and gneiss. Fig. 567 illustrates the attitudes of the strata at their place of meeting.

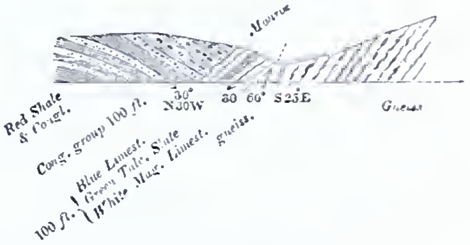


Fig. 567.—Contact of Mesozoic and older Palæozoic Rocks at Monroe.

This belt, which is likewise visible, though less conspicuous, on the New Jersey side of the river, extends W. not farther probably than 1 mile, for no trace of it can be detected on the Old Philadelphia Road, about 2 miles from the river.

Another small belt crosses Durham Creek a little S. of Springtown, and ranges W. as far as the W. branch of that stream. Between this locality and the S. Branch of Saucon Creek there extends another outcrop of the conglomerate, here concealed in many places by the superficial diluvial matter of the adjacent hills. We again meet with it on the Hosasock Creek, but at this spot the rock consists chiefly of silicious and gneissic pebbles. Entering Berks County, a small tract of it is seen near the main branch of Perkiomen Creek, crossing the road from Metztown to Sumanytown. Here it has been quarried for the purpose of conversion into lime; it is composed almost exclusively of angular or very slightly rounded fragments of limestone, and might, upon a careless inspection, be mistaken for a brecciated form of the Auroral Limestone. The calcareous conglomerate, cemented by the material of the red shale, next shows itself on the Manatawny Creek. Following the margin of the red-shale formation to its intersection with Limekiln Creek, a small tributary of the Monokesy, we encounter another local patch of the same rock. Another much larger and wider belt of it commences E. of the Perkiomen Turnpike, about 3 miles E. of Reading, and curving S. and then W. round the base of Neversink Mountain, crosses the double loop of the Schuylkill River about 2 miles S. of that town. The roadway of the Reading Railroad exposes in fresh excavations the strata of this interesting rock, and there is perhaps no locality in the State where it may be more easily studied than in the belt now referred to.

The accompanying cut pictures an exposure on the side of the Reading Railroad, near the S. base of Neversink Mountain, which shows the Mesozoic conglomerate lodged in a cleft of the steeply-upturned strata of the Old Auroral limestone, from the wreck of which, and the Primal sandstone of the mountain, the pebbly matter is chiefly derived. It illustrates well the action of the turbulent waters, which appears first to have scoured sharply the limestone floor of the formation, eroding it into deep gutters by removing the softer or most crushed layers, and then to have cast in without stratifying the promiscuous mass of loose materials which they were dragging with them at the foot of the hills.

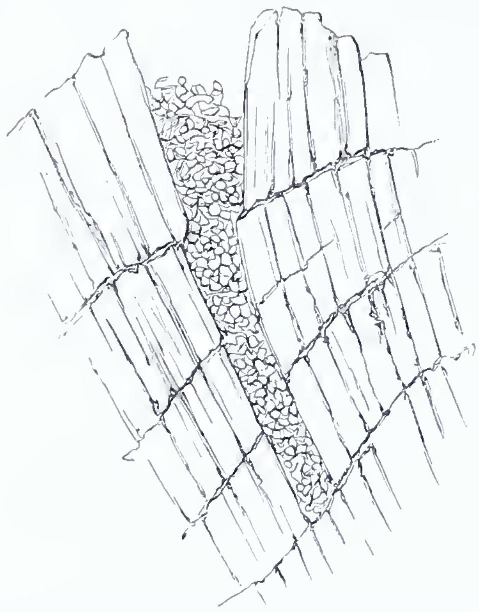


Fig. 568.—A Chasm in the Auroral Limestone, S. foot of Neversink Mountain, Reading, filled with Upper Mesozoic Conglomerate.

Between the Schuylkill and the Susquehanna there are few or no tracts of this upper calcareous conglomerate, a fact readily explained by adverting to the marked difference between the topography of the N. border of this portion of the Mesozoic basin, where the chain of the South Mountains is interrupted, and the other parts of the belt where this barrier was everywhere present with its steep slopes to supply the coarse pebbly materials. This will be made more intelligible in a future part of this Chapter, where I shall offer some views respecting the physical circumstances which accompanied the formation of the Mesozoic deposits.

Passing the W. side of the Susquehanna, we meet with the upper calcareous conglomerate, constituting a much more continuous belt than exists between the Delaware and Schuylkill rivers. It ranges with but little interruption along the N.W. border of the red shale, crossing Cumberland, York, and Adams counties along the base of the South Mountains, the whole distance to Maryland, or, more correctly, into Virginia.

UPPER CALCAREOUS CONGLOMERATE SOUTH-WEST OF THE SUSQUEHANNA.

The upper conglomerate forms, as already stated, the N. boundary of the red-shale formation from the Susquehanna, along the S. base of the South Mountain to the Maryland line a little West of Emmettsburg.

It occurs on the Susquehanna, where it is very imperfectly exposed about 1½ miles below the mouth of Yellow Breeches Creek. From this point it ranges nearly W. along the N. side of the Northern Trap Ridge, above Etter's, and crosses the Yellow Breeches Creek into Cumberland County, near Grove's fulling-mill, about 2 miles N. from Lisburn.

About a mile N. from Grove's fulling-mill the belt of conglomerate is intersected by a ridge of trap which crosses into Cumberland County. Here is a singularly-shaped elliptical mound, about 200 yards long, and 50 feet high, and remarkably narrow at the summit. This hill contains a rock which is evidently an altered calcareous conglomerate.

Near Grove's fulling-mill, and along the banks of the creek towards Lisburn, the conglomerate is seen exposed in very massive beds, but is considerably more impure, that is to say, less calcareous, and more silicious than farther down the creek. Opposite Lisburn, on the York County side, it is exposed in enormous beds, which are, however, much interstratified with red sandstone and shale. It is also seen below Lisburn on the Cumberland side, in the neighbourhood of the forge, where, with its alternating strata of red shale and sandstone, it cannot be less than several hundred feet thick. Some of the imbedded pebbles here are as large as a man's head, or even much larger, making a rock ofsuch coarse structure that cabinet specimens cannot well be selected. These imbedded masses are generally of various-coloured limestones, with some grey and reddish quartzose rock, or very compact sandstone, and some white igneous quartz.

The N. and N.W. limit of the red shale, on the Cumberland side of Yellow Breeches Creek, is about 2 miles from Lisburn, where it stretches S.W. to the creek S. of Bryson's, and a little below Grove's flour-mill. The conglomerate is seen E. of Bryson's, 2½ miles W. from Lisburn ; it again appears on the bank of the creek near Cocklin's mill, above Grove's ; and S.W. from this towards Dillsburg, we frequently see loose in the soil the large rounded limestone pebbles which have come from the decomposition of this rock.

This is also the case immediately above Dillsburg, and on the W. and N.W. of the town the rock appears in place. Near Prosser's mill it is altered to almost a white colour by the influence of a dyke of trap-rock, which is abundant about Dillsburg.

About a quarter of a mile N. of Dillsburg, in a meadow on the farm of Mr Weltz, there is a deposit of white clayey marl formed from the decomposition of this rock. It is covered with a foot or more of dark vegetable soil. This white calcareous mud would seem to be well worthy of trial as a manure.

The altered conglomerate is seen in many places in the immediate vicinity of Dillsburg, frequently on the sides of, and between, the little trap hills ; it is generally of a whitish colour, with a more or less crystalline texture.

The E. termination of the South Mountain is near Dillsburg : there are here two ridges, the more S. one terminating a mile or more S.W. from the town, and the N. one, about 1¼ miles W. from the town. The calcareous conglomerate is distinctly exposed along a deep ravine worn by a little mountain-stream, which sinks into a fissure in this rock, and totally disappears. At this place the cliffs are 30 or 40 feet high, and the rock very coarse, consisting chiefly of round or flattish kidney-shaped lumps of several varieties of limestone (some weighing perhaps 50 pounds) imbedded in a coarse reddish cement.

On the farm of Mr Koontz, near the foot of the S. ridge of South Mountain (about 6 miles N.E. from Petersburg), loose pieces of limestone are abundant in the fields, and some excavations have been made in a bank disclosing many of these loose masses. No rock is visible in place in this vicinity.

At Buckholder's, nearly a mile farther S.W., and near the foot of the sandstone ridge of the mountain, there is an exposure in the steep bank of a small stream, where the rock is exceedingly coarse, consisting of loose rounded masses of limestone of different kinds and colours, with nearly an equal mixture of sandstone and quartzose pebbles cemented by a red-shale paste.

From this point S.W. to within a mile of Petersburg no rock is seen in place ; but the innumerable pebbles of reddish and grey very compact sandstone and quartz in the soil of the little hills along the S. side of the mountain, seem to have come from the conglomerate, which is here losing its calcareous character. At Robinett's, about a mile E. from Petersburg, there is a small exposure in a meadow-bank of a conglomeritic limestone, which wants, however, the red colour so characteristic of the calcareous conglomerate. This is in the immediate vicinity of two other bands of limestone, of which we shall have occasion to speak hereafter.

At Feazier's, 1 mile N.W. from Petersburg, we find the rock only slightly calcareous, and of a grey colour. It is here quarried for a building-stone. A long belt ranges S.W. from this spot, in which, however, it does not appear in place ; the hills abound in rounded pebbles similar to those of the rock.

We next meet with the conglomerate in place at John G. Minter's, 2 miles N.N.W. from

Mummasburg, where it has been quarried in the hope of burning it into lime (much in request in this neighbourhood), but it appears to be too silicious, and to contain too little lime.

At Shull's, on the North Branch of Marsh Creek, near the foot of the mountain, three-fourths of a mile N.E. from the Gettysburg and Chambersburg Turnpike, at Cashtown, the conglomerate is exposed on both sides of the stream. It is seen to be 15 or 20 feet thick, and is very similar to that at Minter's. Above this in an orchard, and in the fields nearer the mountain, are loose fragments of from 20 to 50 pounds weight of a limestone which has possibly come from large masses in the conglomerate, though it seems to have a different character, and may more probably have come from some hidden outcrop of the Auroral limestone, which, there is reason to suspect, occurs in several places along the S. side of the mountain, where it is not covered by the Mesozoic deposits.

Crossing the Gettysburg and Chambersburg Turnpike near Cashtown, and still keeping near the foot of the mountain, we find the conglomerate near Fairfield (commonly called *Millerstown*), consisting almost entirely of limestone pebbles. At Gilbaugh's, 1 mile E. from Fairfield, it is in immediate contiguity with a dyke of trap-rock, and is altered to a crystalline limestone. About a quarter of a mile farther N.E., a greenish shale apparently overlies it, and dips about 18° N. Three-fourths of a mile S.W. from this point, on the N. end of the hill S.E. from Fairfield, there is an altered white conglomerate containing large pebbles; it lies at an elevation of 60 feet above the level of the valley at Fairfield, where the red conglomerate is found unaltered; but it is nearer the trap. At both of these last localities the rock has been quarried for limestone.

The pretty village of Fairfield is situated in a very level tract of land between the trap ridges on the E. and S.E., and South Mountain on the N.W. and W. Throughout much of this valley the conglomerate prevails, and is generally of a superior kind, equalling perhaps the "Potomac Marble" of Maryland. It also appears on Tom's Creek, South from Fairfield, on the road to Emmettsburg. This rock finally passes between the trap hills to the E. of McDevitt's mill, and the spurs of the South Mountain, across the Maryland line a little W. of Emmettsburg, though the valley is here so narrow that it is seldom exposed, and much of it has been removed by denudation.

CHAPTER IV.

TRAP DYKES OF THE MESOZOIC BELT, AND ALTERATIONS PRODUCED IN THE STRATA IN CONTACT WITH THEM.

As a detailed specification and description of all the trappean outbursts of the Mesozoic red-sandstone belt would involve much needless repetition, and serve only to fatigue the reader, I shall restrict myself to an enumeration of the more prominently interesting ones, and refer the student to the Geological Map for further information respecting the localities, courses, and relative magnitude of the various dykes.

Beginning at the Delaware and proceeding Westward, the first conspicuous masses of trap which we encounter are the three large dykes which approach the river below New Hope. These are nearly in a line with the outbursts of trap visible on the New Jersey side of the Delaware, and known as Smith's Hill, Belle Monte, and Goat Hill. The most Southern dyke is a long and narrow one, extending from near the little village of Pineville to within a mile of the river; the second is the bolder outburst of Bowman's Hill, and the third the still larger mass of Lackawissa Hill, these two last terminating near the river. The last-named ridge, the extension of Goat Hill of New Jersey, is connected with some extremely interesting phenomena of alteration and segregation in the adjacent strata on both sides of the river. Perhaps none of our trappean dykes disclose these effects so well. The following description of these metamorphic features is taken from my general account of the Geology of the State of New Jersey.* The rock constituting this great dyke is for the most part, especially in the central portions of the dyke, coarsely granular, being composed of large crystals of a yellowish-white felspar, traversed by elongated tabular crystals of green hornblende of considerable size. It bears no remote resemblance to some varieties of sienite.

"Along the N.W. base of this ridge, on both sides of the river, the strata dip as usual, but are affected in a striking manner in their structure and composition for at least a fourth of a mile from the trap. In the quarry N.E. of Lambertsville we discover the commencement of the change. There the red sandstone, varying but little from its ordinary colour, and being only rather more compact, contains a multitude of large spheroidal nodules of pure green *epidote*, many of which are at least an inch in diameter. They seem not to be distributed promiscuously through the rock, but to be arranged somewhat in layers parallel to the planes of the strata, though they are often several inches asunder. Two or three hundred feet nearer to the trap, we find the rock darker and harder, and the number of nodules greatly augmented, though they are generally of much smaller size. The common colour of the rock is here a very dull purplish blue, and that of the included nodules a dull black or a deep blue. They are of all sizes, from minute specks to the dimensions of a large hazel-nut, and possess every shade of distinctness contrasted with the material enclosing them. They seem to consist of some imperfectly-formed mineral, apparently tourmaline in a semi-crystalline state. These spherical nodules or specks are oftentimes surrounded by a crust or coating of another material, usually nearly white; and I have remarked that the more obviously formed this crust appears, the more crystalline or fully developed is the interior kernel, which at this spot seems to approximate in its features to black schorl or tourmaline. A few hundred feet nearer to the trap, or almost at its base, the rock presents a still different aspect, being of a dark-grey hue, and somewhat coarse-grained. It seems to have been a sandstone, containing little or no clay, as it has nothing at all of the baked jaspery texture of that previously described, which has plainly been either a shale or a very argillaceous sandstone. This grey rock is speckled with innumerable small crystals of very regularly formed *tourmalines,* some of which are more than half an inch in diameter. Upon the opposite side of the river, below New Hope, we meet with very nearly the same order of things, except that the rock containing the completely-formed tourmalines is absent.

"In one thin layer of the altered red argillaceous rock on the Pennsylvania side, the mass, which is of a pink hue, contains, blended with the crystallised *epidote,* some minute but perfectly-formed crystals of a mineral, apparently *idocrase,* of a beautiful wine-colour."

---

* See *Final Report on the Geological Survey of New Jersey,* by H. D. Rogers.

The altered belt here described ranges North-eastward from the river several miles, and has an average width in New Jersey of perhaps a quarter of a mile.

In Tinicum and Nockamixon townships there is an extensive tract towards the N.W. side of the Mesozoic red shale, where this formation is much altered in texture and colour by the presence of a great body of trappean injections. The baked and indurated condition of the rocks has destroyed the capacity usually possessed by the red shales and sandstones to disintegrate into a fertile soil, and the surface of this and all the similar tracts throughout the belt is characterised by cold, wet, and unproductive land. This district, which is several miles in breadth, is known on both sides of the Delaware under the name of the Swamp, from the undrained condition of the soil. It has a general elevation above the river of between 300 and 400 feet, is an undulating and irregular table-land several miles in width, and extends across nearly all the N.W. side of Bucks County. While the metamorphic aspect of the strata is a sufficient demonstration of the near proximity of much igneous rock, only a comparatively small portion of the surface consists of actual trap-rock; and where this material does show itself, it is only occasionally in long and elevated dykes, being oftener in insulated outbursts. One of these latter effusions of the trap is to be seen in the bold elliptical ridge called Haycock Hill, the crest of which is transverse to the more common direction of the dykes, ranging from S.E. to N.W.

A dyke of trap-rock is visible on both sides of the Delaware near Lawry's Island, but some of the injections here seen lose themselves in the cliffs, and do not appear upon the elevated surface of the swamp back from the river.

A careful examination of the natural section exposed at the river will satisfy the observer that the instances of this kind are not unfrequent. It is easy, therefore, to understand why the strata of this whole tract of the Nockamixon Swamp should display such marks of excessive heat, for we are authorised not only to assume the presence of much unseen subterranean igneous matter, but to conceive that, during the rending of the crust and intrusion of the molten trap, much intensely-heated volcanic vapour passed up through the innumerable fissures of the distended and dislocated shale.

Approaching the Schuylkill, we meet with a few short and narrow dykes of trap-rock, but, with the exception of the tracts above referred to, the wide area of Mesozoic rocks embraced between this river and the Delaware is penetrated by scarcely any of these injections. Two or three small dykes occur E. and S.E. of Pottsgrove and the Monokesy Hill, within sight of the turnpike road; and about 6 miles N.W. of that town is a rather copious outburst of this material. South of this section of the Schuylkill, between Pottsgrove and Reading, the red-shale region includes quite a number of short dykes, some of those nearer the river forming the summits of the bold conical hills seen from the river-valley. As all the more conspicuous localities are given in the Geological Map, more special references to the positions of these seem to be unnecessary.

At the mouth of Flying Hill Run, on the Schuylkill, one of these dykes, consisting of very coarsely-crystallised trap, has altered the red shale on the S.E. of it, and the Primal sandstone in contact with it on its N.W. side: these instances of alteration in the rock are very common.

One of the most interesting facts connected with certain of the trap dykes of the district between the Schuylkill and the Susquehanna, is their proximity to extensive beds of a semi-magnetic, semi-hæmatitic iron-ore.

Thus in the neighbourhood of Warwick Iron-mine, 6½ miles E. from Morgantown, there are two or three dykes, the rock being very close-grained.

Another instance is at Jones's Mine, 2 miles from Morgantown, where the deposit of iron-ore, on the margin of the red shale and Matinal limestone, is in close proximity to a regular dyke. But the most striking example of this association of the trap and iron ore is at the great Cornwall Mine, 5 miles S. of Lebanon : this is situated a little within the margin of the red shale, in the line of dykes extending E. from Colebrook. The ore, which occurs here in extraordinary abundance, and in a position uncommonly accessible, is embraced between two parallel walls of trap, where, protected from the action of denuding waters, it occupies the crest of two or three high hills. The presence of so much trap-rock in all the more conspicuous iron-mines of the Mesozoic formation, and the occurrence in each of them of more or less carbonate and sulphuret of copper, so usually associated with the trap, and so indicative of igneous sublimation, all seem to imply some mode of origin for these large deposits of oxide of iron in which igneous or volcanic agency has played a part.

Between Colebrook and the Susquehanna River there ranges the most extensive of all the belts of trap-rock of the red-shale region. The principal dyke forms a rugged undulating ridge known as the Conewago Hills. Its course from Colebrook to Falmouth, where it crosses the river, is nearly from N.E. to S.W., and is therefore not strictly coincident with the strike of the ancient Auroral strata, or floor of the red-shale basin. In this, as in many other instances, therefore, the fused materials were poured out through an actual *rent* obliquely transverse to the strata, and did not rise along the plane of their beds, or even along an anticlinal or synclinal line. The beds of red shale in contact with this dyke are greatly changed in colour, texture, and crystallisation, the total mass, as we approach the trap, being very hard, and graduating from purple to dark blue and greenish black, and acquiring more and more distinctly developed segregations of crystalline green *epidote*.

Northward a few miles from the Conewago trap appear two other conspicuous but shorter dykes : one of these forms the beautiful conical hill called Round Top, the other passes by Rocktown towards the river. The first of these has developed crystals of plumbago in the calcareous conglomerate in contact with it, while that of Rocktown is connected with alterations in the adjacent red shales, precisely analogous to those induced by the Conewago outburst.

Hill Island, in the Susquehanna near Middletown, consists almost wholly of trap-rock, and is nearly in the prolongation of the Rocktown dyke.

A long and slender dyke ranges from a point about one mile S. of Elizabethtown, in a S.S.W. direction to the river, parallel with the general course of Conay Creek. Its N. half is in the red shale, while its S. intersects the Auroral limestone E. of Bainbridge. This dyke crosses the channel of the Susquehanna, and is seen in a little island below the small village of New Holland. Whether the narrow dyke occupying the crest of the ridge penetrated by the tunnel of the Lancaster and Harrisburg Railroad is a portion of this outburst, or an independent injection, is a point we did not satisfactorily determine.

TRAP DYKES WEST OF THE SUSQUEHANNA.

Entering now the third division of the Mesozoic basin, the first trap-dyke W. of the Susquehanna appears upon the shore a little above York Haven. It forms a ridge which ranges nearly N.W., passing Newberry and to the E. of Lewisburg to its termination, in a point near Yellow Breeches Creek 2 miles N.E. of Lisburn. Here it seems to unite with another nearly parallel and conspicuous line of trap-rock, coming from Hill Island and the shore of the river opposite, and which, after following the W. side of the river for nearly 4 miles, sweeps gradually Westward, and joins this first or Southern dyke. These two bold ranges of trap-rock enclose the little red-shale valley of Fishing Creek.

The altered shales and sandstones along the trap ridges contain epidote and micaceous oxide of iron, and the sandstone about Newberry contains in its cross-joints, and of course on the surface of the loose fragments, abundance of micaceous oxide of iron in thin laminæ : some small lumps of iron ore, slightly magnetic, were also found near the town. From the junction of these ridges N.E. of Lisburn, a dyke of trap crosses Yellow Breeches Creek below Grove's fulling-mill into Cumberland County : the altered conglomerate accompanying it has been already described. The trap here is more fine-grained and compact than that of the main ridges on the York County side ; this, however, will be found almost uniformly the case with narrow trap dykes—the rock in the broad ridges being sienitic, having felspar for its base, frequently crystalline, and containing dark and greenish crystals of hornblende, while in the smaller ridges and dykes it is more homogeneous, with a bluish-grey or blackish colour, and is very compact and tough. The dyke here mentioned passes about 2 miles from Lisburn on the N., and appears to terminate at a point about a mile from the creek. On the N. and N.E. of it the Matinal limestone is in place, that portion of it nearest the trap being altered to nearly a pure white sparry rock.

Another dyke runs off S. from the main ridge near Newberry, crossing the Conewago about a mile above Demuth's mill, and passing W. of Strinestown, and probably connecting with the dyke observed in the limestone 1½ miles W. of York. The trap-hills on the W. of Lewisburg are not connected with those on the E. towards Newberry, neither are the shale and sandstone along Bennet's Creek, which runs from Lewisburg S.E., changed from their usual colour and appearance.

About 2 miles S. from Lewisburg, on the right of the road from that place to York, is the most Easterly point of a long trap-ridge, which ranges nearly S.W. from this place, passing near Rosstown, Hampton, New Chester, and so on, S. of Hunterstown ; 2 miles S.E. from Gettysburg it finally crosses the Maryland line, about 3 miles N.E. from Emmettsburg. This ridge is on an average about 1½ miles in breadth, and as the rocks in contiguity with the trap are generally altered in proportion to the mass or thickness of that rock, we find on both sides of this range the metamorphosed shale, extending to a distance about equalling the width of the trap, though this is not uniformly the case.

The trap-rock of the S. ridge is exceedingly uniform in character throughout its whole length ; it is of the coarse or sienitic variety, and is a beautiful and useful material, when artificially dressed, for architectural purposes. A mile S. of Gettysburg we have, on either side of the trap, a dark purplish shale ; but on the W. slope of a hill on the Hanover Road, three-quarters of a mile from Gettysburg, is a belt but a few feet thick, of a lighter colour, exceedingly tough and compact, which contains a little copper with incipient crystals of epidote. About 2½ miles S. of Gettysburg, a little below the turnpike bridge over Rock Creek, is an old quarry in the altered shale S. of the trap, where several varieties of crystallised zeolite are found ; but having been exposed for some time to the weather, the specimens obtained are not so fine as if freshly dug. In a bank on the other side of the stream, zeolite is also found mixed with epidote ; the flat tabular masses showing the crystals of the two minerals curiously interlaced. Nearer Gettysburg, and rather on the N. side of the trap ridge, epidote is abundant in the loose fragments scattered about the fields, some of it mixed with crystals of quartz, some of it with bladed crystals of hornblende ; other specimens are found, but in small quantity, containing along with the epidote a curiously radiated quartz. It seems to be a general, and doubtless a very natural consequence, attending the trap ridges in this region, that they have altered the shale in their vicinity in proportion to their width on the mass of the trap-rock. Thus we find the broad ridge S. of Gettysburg to have exercised its influence for half a mile at least on the contiguous shale, while the narrow dyke on the W. of the town has only 50 or 60 feet of altered rock accompanying it, as we shall hereafter have occasion to note when speaking of the cuttings on the Gettysburg Railroad.

It has been already observed that the most Easterly point of this S. trap range is about 2 miles S. of Lewisburg, and that it does not cross Bennett's Creek, and connect with the Newberry and York Haven range ; on the contrary, it suddenly sweeps round N.W., passing up the course of Stony Run west of Lewisburg, and spreads out into a broad, rough, hilly region, about Stevenson's Mountain, Round Top, Rich Hill, &c. The latter-named hill, however, is only trap-rock on the E. side, the W. being sandstone and shale. From Stevenson's Mountain and the adjacent hills the trap passes in a broad range N. by Siddonstown to Yellow Breeches Creek, about 3½ miles above Lisburn. It does not, however, cross that stream, except in a narrow dyke already noticed, a little E. of Bryson's, on the road from Lisburn to Carlisle. In this trap, on the S. side of the creek, opposite Hursh's mill, we found a heavy, dark, peculiar iron-ore ; but it is not to be procured in great quantity. It is immediately on the bank of the creek. From the trap on the S. of Yellow Breeches Creek, N.W. from Siddonstown, a dyke seems to extend S.W., passing a little North of Dillsburg to the S.E. base of South Mountain. Another branch passes from the neighbourhood of Stevenson's Mountain, ranging S. of Dillsburg, and probably connects with the last-mentioned branch near the base of South Mountain, W. of Dillsburg. In fact, the whole region in the vicinity of Dillsburg consists of trap dykes, altered calcareous conglomerate, and shale, with diluvium and low meadow-ground, so mixed as to make the tracing and describing of each accurately a work of more labour than real utility. Passing from Dillsburg, S.W. towards Petersburg (York Springs), we cross obliquely the trap range which runs from the hilly region E. of Dillsburg to the S. base of the South Mountain. About 2 miles from Dillsburg we leave the trap, and half-altered shale for a mile or more, and then pass on to the common red shale, which continues to Petersburg. About 3 miles S.E. from Petersburg, and not far from the junction of Bermudian and Latimore creeks, seems to be the E. termination of another trap range, which, passing S.W. near York Springs, Heidlersburg, &c., nearly touches Gettysburg on the N., and between that town and the Maryland line approaches very near to, if it does not actually connect with, the great range passing S. of Gettysburg. This second trap-ridge does not appear to be so uniform in its development and character as the S. one, being more irregular and interrupted in its course, and presenting coarser and finer varieties in the crystallisation of the rock. Near the Huntingdon Meeting-house, at the E. termination of the range, the rock is sienitic, showing crystals of hornblende imbedded in felspar. On the bank of Bermudian Creek, at York Springs, the trap-rock is seen on both sides of the stream. The spring issues from the low ground in the gap made in the trap-rock by the passage of the creek, and is so little above the level of the stream as to be overflowed by a moderate rise in its waters. A small trap-dyke crosses the turnpike about a mile S. of the springs. The strata to the S. and S.W. of the springs are altered bluish and purplish shales.

The trap formation, which ranges along near the S. base of South Mountain, passes about 2 miles N. of Petersburg, continuing, with some slight interruptions, S.W., passing near the Lutheran Church east of Bermudian Creek, thence along the N. side of Chestnut Hill, crossing Opossum Creek, near Keener's mill, and so continuing nearly the same course to the turnpike which runs from Gettysburg to Mummasburg. Crossing this nearly 3 miles from Gettysburg, it is seen in the cutting on the railroad about 2 miles from Gettysburg, and ranges thence W. of Willoughby Creek, appearing at Moritz's, on the Emmettsburg Road, W. of Marsh Creek, a little S.W. of which it crosses the State line into Maryland. This *third* trap-range, like the second, is much inferior in width, and effect on the neighbouring rocks, to the *first* or Southern ridge.

Associated with this trap, about 4 miles W. of Petersburg, is an iron ore, which was formerly worked by Messrs Duncan and Mahon at Chestnut Grove furnace, a little S. of Whitestown or " Middleton," as marked on the State Map. This ore bank, as well as the furnace, has been for several years abandoned, and all is going to ruin. The diggings have been deep and extensive, but the ore seems not to have been abundant. It is a compact dark ore, approaching the magnetic variety, and has some micaceous iron associated with it. In the ore-bank at the old furnace we found some specimens containing beautiful crystals of octahedral iron. Near Ludwig Group's, between the old furnace and the mines, lumps of micaceous oxide of iron are found in the fields. In the same range E. of Opossum Creek, and N. of Chestnut Hill, at Carson's, it is also found tolerably abundant on the surface. Some small pieces were found near Wilsonville, W. of Opossum Creek.

We come now to speak of a *fourth* range of trap, which seems to lie immediately along the base of the South Mountain, or rather to appear at intervals along the spurs which form the S. flank of that range.

This trap is apparently much more irregular, less continuous, and more frequently interrupted in its course than any of the others, and may more properly be regarded as a series of dykes. It is generally in close contact with the South Mountain rocks. We may suppose it to commence on the N.E., near Whitestown (Middleton), thence extending S.W., and crossing Opossum Creek near Minnich's mill. It appears between Wilson's and Bender's, on the road from Gettysburg to Pine Grove, and again near Griest's and Ellis's, 1½ miles farther S.W. at the foot of the mountain. It is seen on the Conewago below Bell's mill, near the mountain, and forms a considerable hill N. of Mark's mill, on Marsh Creek, 3 miles N.W. from the Gettysburg and Chambersburg Turnpike. In the shale S. of this hill, near Mark's mill, an iron ore is found, which was formerly partially worked by Messrs Paxton and Stevens at Maria Furnace. It is said to have made a good iron, but since the abandonment of the furnace the bank has been neglected, and the diggings have fallen in. Two veins appear to have been wrought about 50 yards apart, and are said to have varied in thickness from 9 inches to 2½ feet, dipping regularly N.W. with the altered shale : some of the ore found near the mill is highly magnetic, readily holding suspended a nail of considerable size. South-west of this spot, the trap of which we were last speaking diverges from the mountain, crossing the South Branch of Marsh Creek, near the turnpike and railroad, passing E. and S.E. of Fairfield (having the conglomerate between it and the mountain), where it forms considerable hills, and so ranging on the Maryland line, it crosses it about 3 miles N.W. from Emmettsburg. Near this trap, at Orr's, between Cashtown and Fairfield, there is a beautiful compact dark magnetic iron-ore, formerly explored to a small extent, but not found to be extensive. The old diggings are filled in.

This trap ridge E. of Fairfield swells out into large hills, and is a mile or more in width; consequently, we find it of the coarser or sienitic variety. It much resembles that of the first or Southern range, and was much used on the railroad for viaducts, being, when dressed, a very beautiful building-stone.

At Welty's, about a mile E. of Fairfield, and a little W. of this range of trap, is a place where some digging was done several years since in search of copper. The overlying rock is an altered shale dipping W. about 50°. Among the rubbish thrown from the old mine we found some green carbonate of copper, mixed with micaceous oxide of iron, and some micaceous iron.

On the E. side of the last-mentioned range of trap hills, near the road from Fairfield to Gettysburg, is a band of the altered shale of a black colour, which, as usual with black slates, has caused some trouble in the neighbourhood in a fruitless search for *coal.*

About 5 miles S.E. from Fairfield, and 1 mile N. from the State line, near Emmettsburg, in the altered shale a quarter of a mile S. from Abraham Eiker's, are large lumps of iron ore, compact and crystallised. Half a mile farther W. some digging has been performed for iron ore, but without success. About a mile S. of this spot are some very old diggings, made beyond the memory of the present inhabitants of the neighbourhood. Micaceous oxide of iron was found among the old rubbish.

The trap dykes and altered rocks of Adams County are well exposed in the cuttings of the Gettysburg Railroad. The first rock-cutting is through the ridge immediately N.W. of the town of Gettysburg—the *second* trap ridge of our previous account.

The following sketch (Fig. 569) will give an idea of the appearance of the rocks in this cutting.

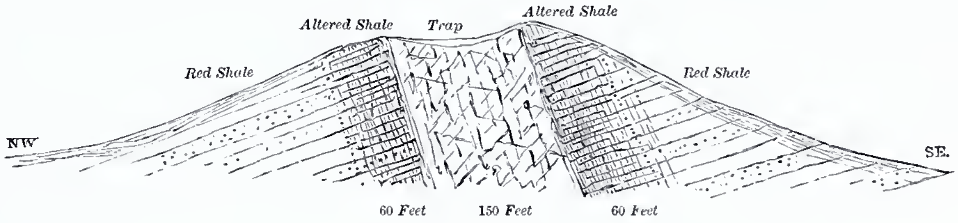


Fig. 569.

The altered shale on the S.E. side of the trap extends about 60 feet from the dyke, gradually changing its colour and quality until it imperceptibly shades into common red shale. The trap-rock is 150 feet wide, and dips 70° S.E.; its true course or strike is N. 12° E. It is much decomposed on both sides, where it is in contact with the shale. The altered rock near the contact with the trap on the N.W. side, like that on the other side, is about 60 feet wide before it resumes its red colour.

There is a thin band of copper-bearing slate in red shale N.W. from the trap-rock.

Between this and the next trap range occur a series of gentle ridges, through all of which the road is cut, showing altered shale in the middle of each ridge, and red shale on either slope towards the intervening embankments across the low grounds between the ridges. This may be caused by a succession of small trap-dykes, which have never reached the surface, but have altered the shale above them. This shale, being thus hardened, and rendered less subject to decomposition, has naturally formed ridges, while the softer red shale, crumbling more readily by atmospheric action, has, in the progress of decomposition and denudation, formed a series of little valleys between.

The third trap-ridge crosses the road about 2 miles from Gettysburg. A calcareous band, 10 inches thick, occurs in the altered rocks contiguous to this ridge. The trap of the third ridge is inferior in width, more jointed and decayed, and also in thinner blocks, than that of the second ridge near Gettysburg. Some asbestos is contained in the joints of this trap; a rough chalcedony was also found in the fissures of the trap-rock, containing the impressions of some cubic crystals, possibly sulphuret of iron.

We meet with a black altered shale 400 yards S.E. of the fourth trap-ridge, which crosses the railroad and turnpike near the gate 3 miles from Gettysburg. South-east from this trap there is a ridge of hard altered rock, in which the cutting is in a very unfinished state, much of the ridge having had none of its rock exposed. The trap-rock lies on the N.W. side of the ridge, and seems to occupy the whole of the low ground between this and the next small ridge near Marsh Creek, where the trap is found on the S.E. side.

Crystals of *zeolite*, &c. are found in the interstices of the trap-rocks. This trap seems to be about half a mile wide, but is only visible at the railroad on its two sides, the middle portion being on low ground where there is an embankment.

Near this place the railroad turns more to the W., and passes through low ground, crossing the turnpike near Marsh Creek, and continuing along the flats near that stream for some distance. A few small cuttings in red shale are seen; but the next cut of any importance is near Biesecker's, not far from the foot of the mountain, and between 3 and 4 miles N. from Fairfield: here a spur of the trap is cut through. This rock seems somewhat laminated or stratified, and dips gently W. The interstices contain several varieties of mineral matter, as zeolite, prehnite, crystals of yellow ferruginous sulphuret of copper, and carbonate of lime.

A single specimen of pale-blue chalcedony was likewise seen.

The next cutting is near Marshall's, one mile farther S.W., in a grey compact silicious rock, which belongs to the Primal sandstone of the South Mountain.

ORGANIC REMAINS AND GEOLOGICAL AGE.

The Red Shale and Sandstone formation of the Atlantic Slope in Pennsylvania has hitherto disclosed but few fossils, but these vestiges of extinct organic life are very significant and interesting. Besides a few rather indistinct impressions of plants, the deposit contains two or three species of crustacean animals, and the remains of two remarkable Saurian reptiles, the *Clepsisaurus Pennsylvaniensis* and *Centemodon Sulcatus.* The crustacean remains belong to two species of the genus *Cypris;* the fossils being minute, flattened, oval, seed-like bodies, not as large as a grain of mustard seed; also two species of the genus *Estherea,* flat, ovoid, shell-like fossils, resembling the *Posidonia minuta,* from which, however, they differ in the markings of the surface, and in the absence of the characteristics of the testaceæ of shell-fish.

The reptilian relics are the teeth and bones of large aquatic lizard-like creatures. The *Clepsisaurus* remains were first discovered in the uppermost layers of the formation near Upper Milford, on the S.E. border of Lehigh County. Their anatomical affinities were investigated and published by Isaac Lea, Esq. of Philadelphia. Subsequently a tooth, referable, if not to the same genus, at least to some allied Thecodont saurian, was found by us at the Phœnixville Tunnel, Montgomery County. Along with this tooth, a figure of which is here presented (see

Fig. 570), specimens of coprolite were found imbedded in the same rock, and subsequently there have been discovered a Saurian bone and a tooth, conjectured by Mr Lea* to be a portion of either the *Clepsisaurus Pennsylvanicus* or the *Centemodon Sulcatus.*

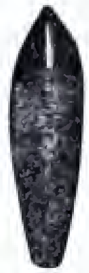


Fig. 570.

It is an interesting circumstance, that while a saurian existed during the deposition of nearly the uppermost or latest member of the formation, there were reptiles in the same waters early after the commencement of it. The vertebral bones of the Clepsisaurus of Lea are slightly concave, or dished, at both their articulating surfaces, and the name has been conferred on the genus in allusion to this hour-glass resemblance.

Much uncertainty has prevailed in the minds of American geologists respecting the precise geological age of this Red Sandstone formation of South-east Pennsylvania. Until twenty years ago, it was conjectured by the late William Maclure, Esq., R. C. Taylor, Esq., and others, on analogies of composition, to represent the Old Red Sandstone of Great Britain; but in 1836, in a report upon the geology of New Jersey, we proved that its date of deposition was certainly later than the upheaval of the Coal-measures in the Appalachian Mountains, and we called it the Mesozoic Red Sandstone, preferring to designate it by its general age rather than assign to it a European name and equivalency in the absence of any significant organic remains.

Professor Hitchcock, in his report on the geology of Massachusetts, regarded the formation as the equivalent of the then so-called New Red Sandstone of England.

In 1842, Professor W. B. Rogers adduced evidence, from a few fossils collected by him in Virginia, for referring it to the age of the European Trias, rather than to that of the older New Red Sandstone, to which it was then generally ascribed. Subsequently† he has presented evidence, from organic remains found in the formation of Virginia and elsewhere, for relating it in time rather with the beginning of the Jurassic period than with the Triassic.

Question of Age.—At the present time the views of geologists respecting the date of this red argillaceous sandstone are still divided, opinion preponderating in favour of a Triassic or Jurassic age rather than of a Permian. To understand the evidence appealed to in favour of the several doctrines entertained, it is necessary for us to go aside and note what has been done in developing the fossils of the other deposits kindred to the one under discussion: I shall as usual proceed from the N.E. to the S.W.

In Prince Edward Island there is a group of red sandstone and red-shale strata, separable apparently into two formations, one on the S. side of the island, imbedding what appear to be true carboniferous plants; the other on the N. side, containing remains of a fossil reptile, *Bathygnathus borealis,* the affinities of which, point to a middle secondary epoch. The basin of Mesozoic strata in Nova Scotia is proved to be of post-Carboniferous age, from its resting unconformably in a trough of carboniferous rocks uptilted at the close of the Coal period. No fossils have yet been discovered in it to indicate its epoch more precisely, but we may conjecture it to be coeval with the red sandstone of the Connecticut Valley, and with that of the Middle States, from the near resemblance of its materials to those of these more Southern belts.

---

* See Proceedings of Academy of Natural Sciences of Philadelphia, June 2, 1857.

† See Communications to Boston Society of Natural History, by Professor W. B. Rogers, 1854, *et seq.*

RED SANDSTONE OF THE CONNECTICUT VALLEY.

The organic remains of the Connecticut Valley belt are some of them highly curious, and though not decisive as respects the age of the formation, are very suggestive even upon this point. The vegetable fossils are chiefly Cycadites, Lycopodites, Equisetaceæ, and a somewhat characteristic fern, Clathopteris rectiosculus, a large reticulated fern found at Easthampton, Massachusetts.* This Clathopteris is represented in Europe by the *C. Miniscoides,* a characteristic fossil of the Trias, and the Lias or lower Jurassic formations.

Of animal remains, the best defined are several species of fishes, and the foot-prints of reptiles and of many birds. The fossil fishes belong to the family of the Lepidoides. They were at one time referred to the genus Palæoniscus, but one group of them has been placed by J. H. Redfield, Esq., in a new genus, Catopterus; and another group by Sir Philip Egerton in a newly-established genus, Ischypterus, both of them possessing the homocercal or equally-lobed form of tail not seen in any formations older than the Trias.† But the most interesting of all the organic remains in the Connecticut Red Sandstone are the quadruped and biped footprints above referred to. The former, it is believed, were left by different species of lizards, turtles, and frog-like or batrachian reptiles; the latter by various species of wading birds, some of them of very colossal size. Coprolites, or specimens of the dung of these creatures, have also been occasionally met with. The tracks occur at intervals throughout a distance of more than 80 miles, from Turner's Falls, in Massachusetts southward, and are repeated on successive surfaces through a thickness of more than 1000 feet of strata, measuring this by the usual rule of the dip.

This, as will presently appear, does not, however, necessarily prove a subsidence of the bed of the red-sandstone estuary through so great a space. No actual remains of birds recognised as such have hitherto been brought to light; though a few obscure bones, believed to be reptilian, have, it is said, been discovered. As the bird-tracks here spoken of are the earliest vestiges yet met with in any country of this high class of creatures, an especial interest attaches to the determination of the true antiquity of the rocks which contain them. In a recent communication to the American Association for the Advancement of Science (1858), Professor Hitchcock, in presenting a general description, with drawings, of all the foot-marks, tracks, and trails noticed by him imprinted in the Connecticut red sandstone, displayed impressions which he conjectured might have been produced by mammalian animals of the Marsupial family (the tribe including the kangaroos, opossums, and other pouched creatures), but no mammalian bones have been discovered to confirm this interesting suggestion. Among the tracks are some attributable to crustations—viz., to crabs, crawfish, and the like; while there are others so minute and delicate as to imply that they were formed by insects. The non-discovery of the bones of birds amid strata so abundantly marked with bird-like footprints, has been attributed to the floating away of the carcasses of the birds after death by the waters of the estuary upon whose slimy shores the impressions were left, or to their dying and decaying on the dry land. These ingenious suggestions will not apply, however, to the non-appearance of any remains of the reptilians, inferred, from the footprints, to have coexisted with the birds; and we must acknowledge that this absence of solid relics where analogy drawn from other formations elsewhere teaches us that we should find them, casts some doubt upon the conjecture that certain of the foot-marks were impressed by either reptiles or mammals.

---

* See description by E. Hitchcock, Junr., in *American Journal of Sciences,* vol. xx. p. 22.

† See paper on the "Relation of the Fossil Fishes of the Sandstone of Connecticut and other Atlantic States to the Liassic and Oolite Periods," by W. C. Redfield, in the *American Journal of Sciences and Arts,* vol. xxii. p. 357.

ORGANIC REMAINS OF THE MAIN RED-SANDSTONE BELT OF THE ATLANTIC SLOPE.

Notwithstanding the great extent of this, the chief Mesozoic deposit of the Atlantic States, stretching almost continuously from the Hudson to South Carolina, the number of fossils hitherto found in it is very scanty.

Of *Plants* it has disclosed fragments referable to *Equisetites*, and probably *Zamites*, besides specimens of coniferous wood, either petrified or in the coaly condition called *Lignite.* These vegetable forms seem to relate the deposit to the Triassic or older Mesozoic epoch.

Among the *Animal* remains are two species of Cypris and two species of Estherea, both genera of crustaceans. These have been met with in different parts of the formation in Pennsylvania, Virginia, and North Carolina, but I am not aware that they have hitherto been detected in the equivalent deposit of the Connecticut valley.

Of *Fishes*, several species of the genus *Catopterus* have been discovered in New Jersey, Virginia, and North Carolina, and three of these have likewise been encountered in the Connecticut Valley belt, associated with one or two others of the same type not yet met with farther S.

Another genus, the *Ischypterus* of Egerton, has also been met with both in the New Jersey extension of the Pennsylvania belt and in the deposit of the Connecticut Valley, adding to the palæontological links which tend to identify in age these two disconnected formations.

Of *Reptiles*, the main formation, or that which alone passes across Pennsylvania, has thus far disclosed the remains of several interesting species; two of these, the *Clepsysaurus Pennsylvanicus* and *C. Leai*, were first discovered, as already intimated, in Pennsylvania; and a species, probably the first named, has been since recognised in the deep river coal-field at North Carolina, nearly a prolongation of the same, by Dr Emmons, who has added several other species of reptiles as belonging to the deposit in North Carolina,—namely, *Rutiodon Carolinensis, Palæosaurus Carolinensis*, and *Palæosaurus Sulcatus.* In New Jersey the formation has disclosed the remains of another reptile of the same general structure as the *Clepsisaurus:* it has been named by Mr Lea, who discovered it, the *Centemodon Sulcatus.*

Some of these saurians or lizard-like reptiles of this red-sandstone formation—the *Clepsisaurus*, for example—have been referred to Professor Owen's group of *Thecodont Saurians*, or extinct gigantic lizards, having the inner parapet of the lower jaw almost as high as the outer one, and teeth of a slender compressed conical form, finely saw-toothed on their edges, and closely set in a row between the parapets. A distinctive feature of the teeth is their having the saw-teeth of their margins directed towards the point of the tooth. Much stress has been laid upon these characters, because hitherto they have been restricted to reptilians coming from as low a position in the geological column as the Permian formations. As this is a point bearing directly upon the question of the geological age of the Mesozoic red sandstone, it is important to concentrate upon it as much learned opinion as we can. Now, it is stated by Professor Leidy of Philadelphia, who devotes to the Fossil Osteology of the United States an uncommon share of acuteness, patience, and learning, that the *Clepsisaurus* of Lea found in the rocks of Pennsylvania and

North Carolina "is not properly a Thecodont reptile, but may form the type of a new family, as its teeth are inserted in the jaw by solid conical fangs."* Such mode of insertion is clearly indicated in the teeth procured from the Phœnixville Tunnel. So far, then, as the reptilian remains have a bearing, the question of the geological age of the formation rests very much where it was before their discovery. The removal of the *Clepsisauri* from the *Thecodonts*, like the previous setting aside of the fishes of the formation from the Permian genus *Palæoniscus*, withdraws every Palæozoic link, and leaves us nothing to countervail the evidence of a Triassic or still later date, deducible from the affinities of the other organic remains.

Along with the fossils hitherto discovered at the Phœnixville Tunnel are some scales of ganoid fishes, and remains of bones and teeth conjectured by Dr Leidy to be batrachian.

FOSSILS OF THE MESOZOIC BELTS OF VIRGINIA AND NORTH CAROLINA.

Confining our attention, in the first place, to the most Western of the three Mesozoic deposits of the Atlantic Slope of Virginia and North Carolina, as being the belt which is most evidently the representative of the red-sandstone tract of Pennsylvania, and looking at its distinctive fossils, we find the plants to resemble very nearly those of the carbonaceous deposits of Whitby and Scarborough, in Yorkshire, near the base of the English Oolitic or Jurassic series. Among the forms of fossil vegetation are a species of Zamite and the *Equisetum Columnari*. Besides these plants, the formation contains two species of *Estherea*, formerly regarded as *Posidonomya*, and two of Cypris, one smooth, the other beautifully granulated. One of the *Esthereas* resembles closely the *Posidonomya Brownii* of the European *Lias*. According to Professor W. B. Rogers,† who has devoted much attention to the Mesozoic Fauna of the United States, these fossils are all to be met with in the middle and Eastern or coal-bearing belts of the same district in Virginia and North Carolina; and as the more complete series of fossils of these last-named deposits implies an old Jurassic date, he is disposed to regard the main or W. belt as of that age likewise.

Dr Emmons, the able State Geologist of North Carolina, in his recent Geological Report on the Midland Counties (1856), gives a full account of the organic remains discovered by him in the Mesozoic rocks of the Deep and Dan rivers. He conceives that these deposits embrace strata of two distinct periods: a lower series, consisting of conglomerate, red sandstone, coal, and fire-clay, calcareous and bituminous shales and drab-coloured sandstones, equivalent to the *Permian* of Europe; and a conglomerate, a blue slate with coal and fossil plants, and red sandstones and marls equivalent to the European Triassic. In the lower he finds various forms of vegetation—namely, several species of *Fucoids*, or sea-weeds, chiefly of the genus *Chondrites*, and *Equisetum*, the *E. columnaroides*, some *Lycopodiaceæ* or *Club-mosses*, and two or three species of *Ferns*. Among the *Animal* remains are one species of *Cypris* in great abundance, and an *Estherea* or *Posidonomya*. He states that the remains of fishes, chiefly small shining rhombic scales of the ganoid type, are numerous in the black bituminous slates. They seem to belong to the genus Catopterus; but the most remarkable of his discoveries are the relics of several reptiles, a *Clepsisaurus Pennsylvanicus*, *Rutiodon Carolinensis*, *Palæosaurus Carolinensis*, and *Palæosaurus Sulcatus*.

---

* See Proceedings of the Society of Natural Sciences of Philadelphia, June 9, 1857.

† See Communication to the Boston Natural History Society, 1854.

In the upper group, or the argillaceous blue slates of imputed Triassic age, Professor Emmons has found an equally interesting series of organic remains. Of ferns he describes several species, as *Tæniopteris, Strangeritis obliquus, Pecopteris Whitbyensis,* and others. He shows two new species of Cycadites and two *Zamites,* one of them, the *Z. obtusifolius,* a characteristic plant of the Richmond Coal-field, and two new species of *Podo-Zamites:* besides these are several Lycopodiaceæ and Equisetaceæ, and two species of Sphenoglossum. Among the *Animal* remains are two species of Posidonia or Estherea, and a tibea of a Saurian reptile.

Since the publication of the *Geological Report of North Carolina* in 1856, Professor Emmons has discovered the remains of an insectivorous mammalian animal in the older or supposed *Permian* group of the Deep River Coal-field. According to Dr Leidy,* this mammal, the *Dromotherium sylvestre,* is closely allied to the *Spalacotherium* of Owen, a fossil of the English Purbeck limestone of the oolitic series. This analogy, and the decision previously reached, that the reptiles are not of the Thecodont type, seem to argue against the opinion that some of the Mesozoic rocks of North Carolina are of the *Permian* age. All the evidence from organic remains appears to tend to the conclusion that they were formed late in the Triassic or late in the Jurassic periods. Confirmatory of the testimony derived from the entire absence of any well-authenticated Permian fossils is the evidence from stratification. This exhibits not merely a total absence of a physical division of the series by a break of sequence in the deposits, but the existence of one remarkably homogeneous group, as the description of the several members already cited will clearly show.

For the purpose of correlating more clearly the several Mesozoic deposits of New England and the Middle and Southern States, let us here briefly link them together by the organic remains which they are found to possess in common :—

The main belt of New Jersey, Pennsylvania, and Virginia, and that of the Connecticut Valley belt,	Are identified in time by their both containing the same footprints of birds, &c. ; and the same species of fish,—viz. of Catopterus.
The main belt of Virginia and that of the coal-bearing rocks of Henrico and Chesterfield counties of the same State,	Are linked together by apparently the same species of Cypridæ and Estherea, and by the same plants.
The main belt in North Carolina, that of the Dan River, and the coal-bearing strata of the Deep River of the same State,	Are related by several identical species of plants and animals.

Thus the whole of this long chain of deposits reposing unconformably upon the upturned edges of the Metamorphic and Palæozoic formations of the Atlantic Slope, are to be regarded as very closely approximated, if not identified in time, by the possession in common of important distinctive fossil remains, to be met with nowhere else among the American rocks, but represented in European strata, in part by the self-same species, in part by nearly-related analogies.

These strata are placed in parallelism with the middle Mesozoic formations of Europe—the upper Triassic and lower Jurassic rocks—not merely through the few European species which they possess, but quite as obviously by the general aspect or *facies* of nearly all the organic remains which they have hitherto disclosed. Every year is adding to this list, and, as they multiply, the impression produced leans more and more towards the conviction that they were created in the period which unites the Triassic and Jurassic ages.

---

* See Proceedings of Academy of Natural Science of Philadelphia, June 9, 1857.

PART IV.

IGNEOUS ROCKS AND MINERALS, VEINS AND ORES.

No portion of the Atlantic States, of equal area with Pennsylvania, contains so small an amount of igneous or unstratified crystalline rocks. Even the Atlantic Slope, the metamorphic and crystalline zone of the country, is within this State unusually free from these once molten and intrusive materials, being occupied, to a far larger extent than in the districts to the N.E. and S.W., by sedimentary strata, which have escaped metamorphism. Excepting one solitary narrow dyke of trap-rock crossing Cumberland County, there is a total absence of injected rock anywhere to the N.W. of South Mountain, or the first range of the Appalachian Chain ; and even within this range, which in New Jersey and New York on the one side, and Maryland and Virginia on the other, abounds in mineral veins and dykes, the amount of genuine Plutonic matter is comparatively small. Between the South Mountain and tide-water, or within what I have termed the Atlantic Slope, the chief outbursts of igneous matter are the numerous dykes and outpours of basaltic trap-rock of the Mesozoic Red Sandstone zone, which have been already described in the chapters upon that formation. The other mineral injections of the district, or those which have invaded the strata—metamorphic and unaltered—which are not covered by the red sandstone, are the dykes and veins of granite and greenstone, confined principally to the gneissic belts, and certain veins or lodes of complex composition, interesting for the metalliferous ores and crystalline minerals which distinguish them. I propose to offer in this place some account of these several classes of injections.

Granitic Dykes.—As already mentioned in the earlier chapters of Book I., the S. zones of gneiss include numerous small dykes and veins of granite. This rock is nowhere seen in sufficient mass to constitute a feature in the scenery, or indeed to make itself recognised in other than minute fragments. In the lower part of the State, especially in Philadelphia and Delaware counties, the prevailing character of the rock is that of a triple mixture of very coarsely crystallised felspar, quartz, and mica ; the felspar greatly preponderating, and being very generally in a state of more or less advanced decomposition, passing in some cases into kaolin. Those parts of the gneissic districts which exhibit that formation disintegrated to a greater or less depth below the soil, present the granitic veins rotted and softened to fully as great an extent : this circumstance makes the detection of the granite usually an easy affair, as it is betrayed by the coarse flakes of indestructible mica, and the white decomposing felspar usually contained in the otherwise grey soil of the surrounding gneiss.

The granitic veins observe no very constant direction, though their prevailing strike conforms to that of the metamorphic strata which enclose them. On the banks of the Schuylkill the granite may be seen in many instances to ramify and expire within the gneiss rock, partly intersecting it, and partly conforming to its contortions : it occurs, though much more seldom, in the form of regular dykes or veins of considerable length and thickness, having parallel walls. The few conspicuous injections of this class, such as that which crosses the Wissahicon below Middleton's, have been already specified. A different class of granitic dykes from those bordering the Schuylkill occurs in the S. part of Delaware County. The rock is not so truly a granite as a sienite, for it contains little or no mica, and consists of a vitreous felspar (its chief component), a little quartz, and a little hornblende. This rock appears in wide dykes, which increase in magnitude and frequency as we trace them into the State of Delaware, where the material has long been quarried as a rough building-stone.

Greenstone.—Greenstone trap-rock occurs occasionally in narrow dykes in the metamorphic districts both S. and N. of the Chester County Valley, but these igneous outbursts are invariably slender and obscure. Some of the chief ones have been described in the previous text, and a second detailed reference to them would be superfluous. It is worthy of note, however, that these injections not only intersect the older metamorphic strata of the belts S. and N. of the Montgomery and Chester Valley, but they cut the Palæozoic strata—Primal slates and Auroral limestone—of that tract likewise ; whereas the dykes or veins of the granite are never seen within the limestone, or indeed anywhere outside of the belts of typical gneiss rock. We might hence infer, if this observation is correct, that the granite was intruded at a decidedly more ancient date than the greenstone. There is some reason, nevertheless, to doubt the accuracy of this generalisation ; for, as already shown in Book I. Chapter II., dykes of rotten granite occur in the middle zone of gneiss, near the Yellow Springs, in immediate contact with red sandstone and iron ore, under circumstances which imply their intrusion to have been later than the deposition of the Mesozoic formation, since they seem to occupy dislocations which involve insulated patches of that formation.

The other classes of intrusive matter to be met with in the metamorphic zone of the State—as the dykes of serpentine of Chester County, and the metalliferous lodes of the same county and of Berks and other districts—have been either already treated of in detail, or are presently to receive a special description ; they consequently do not demand any more particular mention here. We will therefore proceed to a detailed account of such of the more interesting veins and localities of crystalline minerals as remain undescribed.

MINERAL VEINS OF THE PICKERING CREEK VALLEY, NEAR PHŒNIXVILLE.

We will first direct our attention to the interesting group of metalliferous injections which occupies a narrow district N. of the great Limestone Valley, and extends E. and W. of the Schuylkill for a few miles, from the neighbourhood of Charlestown Village, in the valley of Pickering Creek, to the Perkiomen Mines in Montgomery County.

GEOLOGICAL RELATIONS OF THE MINERAL VEINS.

It will be seen, upon consulting the map of the mining district of Montgomery and Chester counties, that the metalliferous lodes or veins extending from the Perkiomen Mines in Montgomery County to the Charlestown Mines in Chester County, occur not far from the boundary which separates the gneissic rocks of this region from the Middle Secondary formation of red shale and sandstone. Some of them would seem to lie entirely in the one set of strata, and some of them in the other ; while others again, especially the interesting group of the Pickering Creek Veins—on the economical prospects of which I propose to venture some opinions—are partly within the gneiss and partly within the red shale, penetrating the latter, however, to apparently a trivial extent. It would seem to be a pretty general fact, that such of these veins as are confined entirely or chiefly to the gneiss bear *lead* as their principal metal, whereas those which are included solely within the red shale are characterised by containing the ores of *copper*. But the *zinc* ores, viz. zinc-blende and calamine, prevail in greater or less proportions in both sets of veins, existing, perhaps, in a rather larger relative amount in the copper-bearing lodes of the red shale. Thus the Perkiomen and Ecton Lode, the United Mine Lode, the Shannonville South Lode, a small lode on French Creek, a lode at Port Kennedy, and the Morris Lode near Phœnixville, are genuine *copper* veins, and they are all, without exception, in the Red-shale formation.

On the other hand, the Wheatley and Brookdale Lode, the Chester County Lode, the Montgomery Lode, and the Charlestown Lode, with other adjoining ones of the same group at present more imperfectly developed, all lying within the gneissic rocks, or if extending into the Red shale not explored beyond its mere margin, are equally genuine *lead* veins. This interesting general fact is not presented, however, as an invariable law, unattended by exceptions, for it must be observed that several of the lead veins of the gneiss actually enter the red shale; two of them, the Wheatley and the Chester County Lodes, carrying their ores of lead and the usually accompanying vein-stones into this rock, while some of the others enumerated are traceable still farther within its boundary by their characteristic surface-fragments. Nevertheless, in all these cases the red-shale formation which they penetrate is a very thin and superficial capping, or unconformable covering to the gneissic strata, within which, even here, the chief body of the veins must be contained below this shallow depth. Thus, even in these instances, the exceptions to the rule are more apparent than real. But partial deviations from the law, of another sort, are met with; some of the lead veins of the gneissic strata contain traces more or less abundant of the ores of copper, and, more strikingly, very considerable proportions of lead ore are occasionally associated with the copper ores, in the copper veins of the red shale, especially in the lodes of the Ecton and United mines. Yet even in these last-mentioned instances, which are the most conspicuous exceptions to the general rule hitherto brought to light in the district, the proportions of lead ore to copper ore are quite subordinate, when estimated for each entire lode.

The *gneissic strata* of the tract embracing this group of lead-bearing veins seem to differ in no essential features from the rest of the formation ranging E. and W. through this belt of country. Here, as elsewhere, they consist chiefly of soft, thinly-bedded micaceous gneiss, a more dense and ferruginous hornblendic gneiss, and a thicker-bedded granitic gneiss, composed not unfrequently of little else than the two minerals, quartz and felspar.

A soft, white, and partially-decomposed granite is a very frequent associate of the stronger lead-bearing veins, particularly in their more productive portions; but this material belongs, in all probability, not to the ancient granitic injections of the gneiss, but to those much later metalliferous intrusions which filled long parallel rents in that formation with the lead ores and their associated minerals. It appears to be, in fact, of the same date of origin with these metalliferous lodes, and may be viewed as derived in part or altogether from the fusion of the intersected gneiss, by the intensely hot mineral matter of the vein brought into close contact with the walls of the fissure. The melted constituents of the gneiss have thus floated up along the sides of the true vein, and re-crystallised, upon cooling, in chief abundance upon the exterior of the lode. Soft granitic matter of this sort very frequently adjoins the hanging walls of the less steeply pitching lodes of magnetic iron-ore in New Jersey and New York; and it would naturally tend to place itself in this position, from its superior lightness compared with the metallic matters.

The gneissic strata and their granitic injections throughout this district, display a softened, partially decomposed condition, extending in many places to a depth of several fathoms. This rotted state does not, however, pervade these materials to as great a depth as it does in the belt of gneiss lying S. of the Chester County Valley and nearer the level of the tide. To its influence we must impute the fertility of the soils resting on the formation, and the soft lines of the landscape. Its origin is due, in part, at least, I think, to the action of the sea-water, which once evidently rested over all this S. edge of the low Atlantic slope of the country, dissolving by chemical forces the more soluble ingredients of the felspar, hornblende, and mica.

Immediately adjoining some of the mineral veins at the Wheatley and Chester County lodes, the gneiss is softened and decomposed to a very considerable depth, and, in some places, in a very thorough manner; the more micaceous beds being converted into a crumbling, purplish-red, unctuous, and clayey material, easily crushed in the hand, though taken from a depth of many fathoms. This condition, which has much facilitated the cutting of the upper adits of these lodes, is the result, in all probability, of a chemical influence exerted on the materials of the strata by some of the elements which belong to the veins, or which passed up through the fissures they fill at the time of their injection. Highly-heated steam and other volcanic vapours have manifestly been the agents of many of the changes we witness in the walls of our igneous veins. At the same time, it must be borne in mind that, near the surface, the penetration of external water and its carbonic acid, and free oxygen along the sides of the lodes, may have assisted this decomposition; and there can be no doubt that these elements, thus introduced, by leading to chemical changes and replacements in the constituents of the lodes, have caused the formation of several of the minerals we find—the carbonates and sulphates, for example, which are usually met with in the cavities and nests of the veins.

The dip of the gneiss throughout this district is generally about S. 20° E., and seldom at any high angle, the most common being 30°—40°; but this direction and inclination are, in some cases, much affected by contact with the veins. These *cut* or intersect the beds of the gneiss, both in strike and dip, even where they seem, by the violence of the disruption at the formation of the vein, to have twisted the strata from their ordinary bearings. This intersection or cutting shows these to be true lodes.

Of the *general relations of the mineral veins* of the district to each other, enough is already known to convince us that these lodes are physically associated as members of one natural group of igneous injections, indicating that this is a genuine mineral region, and that the distribution of its metallic wealth is controlled by definite and ascertainable laws.

Of the one dozen or more lead and copper lodes of greater or less size brought to light in this quite limited region of five or six miles length, and two or three miles breadth, the greater number are remarkably similar in their course, ranging N. 32°—35° E., and S. 32°—35° W.; and what is equally worthy of note, they dip, with scarcely an exception, towards the same quarter, or S.E., though in some instances so steeply as to approach the perpendicular. Those which do not observe this direction, seem, as far as traced, to range N. 52°—54° E. and S. 52°—54° W., and by their mutual parallelism to each other, to constitute, as it were, a second subordinate group or system of veins. There are one or two other lodes, such as the *counter-lode* of the United Mine, which range at even a less angle to the meridian than the first or principal set, namely, about N. 26° E.

The point of chief interest is the wonderfully close parallelism of the more numerous group embracing the larger and more promising veins of the district.

There is no marked difference in the general character of the vein-stones of the several mineral lodes, nor any features to distinguish as a class those of the red shale from those of the gneiss, nor, again, those observing the normal direction of N. 34° E. from those of the more exceptional direction of N. 53° E. Yet each vein possesses certain special subordinate characteristics in both its non-metallic minerals and its ores, and even in its surface vein-stones and gossans, by which the initiated observer may recognise its individuality.

The predominant material in all these lodes is quartz, then sulphuret of iron; next to this, perhaps, the sulphate of baryta, though this is a much more variable ingredient, being scarcely seen in the Wheatley and Chester County veins, while in others, as in the Charlestown, Morris, and the United mines, it is in great abundance: besides, these, there occur frequently the materials of the walls of the veins, but in a more or less altered condition; such are the soft, white, felspathic granites in some of the lead-veins, conspicuous, for example, in parts of the Wheatley Mine, and the altered shale and sandstone fragments involved with the ore in the Morris Lode. These veins are recognised and traced on their "backs" or outcrops by fragments of indestructible vein-stones, chiefly cellular quartz and sulphate of baryta, and by their gossans, or masses of pulverulent oxide of iron and ochreous earth, interlaced with quartz, or filling cavities in the lumps of this mineral, and still more definitely by the presence of the metallic ores, sometimes well preserved in the cavities, or in the body of these fragments, or oftener only in stains and surface-coatings of the phosphate of lead or the carbonate of copper.

The different lodes differ more, perhaps, in the amount and distinctness of the gossan which they show on their backs and in their higher levels, than in almost any other particulars. In this excellent indication of a good and remunerative metalliferous vein—an abundance of soft brown gossan—perhaps none of the lodes of the region will compare with that of the Wheatley Mine. This material, the product evidently of the decomposition of the sulphuret of iron of the vein, often contains, in this Wheatley Lode, especially at some depth below the surface, a very appreciable trace of silver, derived, most probably, from the decomposition of argentiferous galena, which is one of the characteristic ores of the vein. Sundry assays of its gossans show an average proportion of about ten ounces of silver to a ton of the material.

The metalliferous and other minerals found in these veins form quite a numerous list.

Selecting the Wheatley Lode, as presenting perhaps the greatest diversity of species, and as that which has received altogether the closest study, we find the mineralogy of these veins represented by the following large and interesting catalogue: Sulphate of Lead, Carbonate of Lead, Phosphate of Lead, Arseniate of Lead, Molybdate of Lead, Chromate of Lead, Chromo-molybdate of Lead, Arsenio-phosphate of Lead, Sulphuret of Lead, Antimonial Sulphuret of Lead and Silver, Sulphuret of Zinc, Carbonate of Zinc, Silicate of Zinc, Sulphuret of Copper, Green Malachite, Blue Malachite, Black Oxide of Copper, Native Copper, Oxide of Manganese, Native Sulphur, Native Silver, Quartz, Cellular Quartz, Oxide of Iron containing Silver, Hæmatite Iron, Brown Spar, Sulphate of Barytes, Iron Pyrites, and two or three other species.

THE WHEATLEY LODE AND ITS MINES.

A prolongation of the Wheatley Vein, entitled the "Brookdale Lode," is really but the extension of the first-named vein, as is apparent from its lying precisely in its course, the line connecting them not deviating, in fact, the amount of half a degree in a distance from the N.E. end of the Wheatley levels, of more than 3000 feet to the engine-shaft on the back of the Brookdale portion. It is furthermore confirmed by the correspondence in the direction of the dip of the two veins, but especially by the close agreement, amounting to identity, between the vein-stones and ores of the respective lodes.

This remarkably regular silver-lead vein, already one of the most extensive, as respects its developed length, in the country, has been opened and mined at intervals along a range of about 3072 feet. It is first approached from near the water-level, from the S.W. side of Pickering Creek by an adit cross-cut of 410 feet through the Red shale; the distance from this point, where the adit turns into the lode to the cross-cut leading from the vein to the main or engine shaft, is 540 feet; thence along the vein to the most Western point now reached in the Wheatley Mine, which is, in the 10-fathom level, 571 feet,—making a total length here wrought, to the date of the 1st of May 1853, of 1111 feet. The main adit-level, including the part in the red shale, is 1279 feet long.

Between the Wheatley and Brookdale engine-shafts, the distance on the lode is 2076 feet, and at the Brookdale Mine the lode has been opened by an adit-level a farther length of 456 feet,—making in all, the developed length already specified of 3072 feet. That the lode is prolonged several hundred feet beyond the present termination of the adit of the Brookdale Mine, is evident to any careful observer; for the surface is marked, in the vicinity of the course of the vein for this space, by lumps of cellular quartz, containing the well-known gossan of the vein, and its distinctive ores and minerals. It is certainly an encouraging feature in the vein that it thus so well preserves all its characters over so considerable a length. Although there intervenes a space of about 1501 feet between the S.W. workings of the Wheatley Mine and the N.E. openings of the Brookdale, within which the lode has not yet been sought for nor proved, there cannot be much doubt that it maintains itself continuously through this interval, and is a regular persistent vein.

In width this vein varies from 1 foot to 2 or 2½ feet, its average size in the Wheatley Mine being about 18 inches, and in the Brookdale adit nearly 2 feet. Thus far it gives all the indications of being about as productive in ore in the latter mine, at an equal depth, as it is in the former. While the Brookdale end is somewhat thicker than the other, it is rather more full of quartz; yet the adit there, which is only some 30 feet below the surface, and is at present rather more than 456 feet long, presents, for 400 feet, what miners would call a "kindly lode for ore," with quartz, gossan, phosphate of lead, carbonate of lead, and galena, growing somewhat poorer, however, farther towards the S.W. end. The Brookdale shaft, descending on the lode, is only 75 feet deep as yet, but the lode seems gradually to improve as the sinking advances.*

The dip of the lode in the Wheatley Mine is about 2½ feet to the fathom, or 68°; while it is steeper in the Brookdale end, being there about 18 inches per fathom, or 76°. Its mineralogical characters have been sufficiently described already, when alluding to it as the type of the more promising lead-bearing lodes of this district. It may be well enough, however, in this place, to call attention to what has been said under the head of "General Remarks" upon these veins, respecting the prevalence of a soft felspathic granite on its walls, a soft rich gossan in its upper levels containing silver, and the gradual reduction in the proportion of the phosphate and carbonate of lead, with a corresponding increase of that of the galena in descending from level to level in the Wheatley Mine. This last fact, showing a progressive replacement of the more easily vapourised ores—condensable only in the upper cooler parts of the vein—by other ores requiring a higher heat to sublime them, gives us, as already intimated in a former statement, a right to anticipate a somewhat further augmentation in the quantity of galena as the mine descends. By indicating the energy of the igneous action which attended the injection of the metalliferous materials in the fissure, these more readily sublimated compounds are in themselves an assurance of the probable permanency and constancy in size of the lode. That this vein is the product of true igneous or volcanic agency from a deep source within the earth, is not only clearly implied by all that has been here stated of its geological and mineralogical features, but is plainly demonstrated by the occurrence of pure volcanic or crystalline sulphur in the cavities of the less compact masses of the galena or sulphuret of lead. Were a conclusive proof of an igneous origin really needed, it would be furnished, I conceive, by this interesting fact. Other and equally striking evidences of the force with which the vein was injected will present themselves in the cross courses of trap-rock, intersected and displaced by the lode. To the description of these I now proceed.

TRAP DYKES OF THE WHEATLEY LODE.

Throughout this mineral district, and indeed extensively over all this part of Pennsylvania, the strata are intersected by dykes or injections of all dimensions, chiefly narrow ones, of a fine-grained bluish trap-rock. These seem to observe one prevailing course, at least a general E. and W. direction of the principal ones has been detected by me. They traverse equally the oldest strata of the region, the gneiss, and the ancient palæozoic limestone of the Chester County Valley, and the newest formation in the district, the Middle Secondary or Red shale and sandstone. It is thus manifest that some at least of these igneous injections are of a date subsequent to the deposition of the red sandstone, and it is highly probable that even many of those included within this tract of the oldest rocks are of the same relatively recent age; yet we have in the Wheatley and Brookdale Lode, which cuts no less than three of these small dykes of trap-rock, the interesting proofs that this lead-bearing vein, and, by analogy, the other metalliferous lodes, are of a date even somewhat more modern. These would appear to be, in fact, the newest of the igneous injections of any sort encountered in all this Atlantic portion of the continent. Their precise geological age is not susceptible of any closer limitation than a date subsequent to that of the formation of the red sandstone, and prior to that of the cretaceous deposits which, in New Jersey, overlap this red sandstone and its trap dykes unconformably, and which, from their embracing no mineral veins whatever, have very evidently been laid down after these I have now described were injected. They may possibly belong either to the epoch of disturbance which attended the elevation and close of the oolitic coal deposit of Virginia and North Carolina, or that other period, of a far greater and wider movement, which shifted the shores and interior basin of the continent, immediately before the vast cretaceous formation commenced its long term of sedimentary accumulation.

---

* At date of August 1, 1853, the shaft was down 110 feet; and a level, at 90 feet depth and 20 fathoms long, exhibited a much richer condition than the adit-level above.

THE TRAP DYKES IN THE WHEATLEY LODE.

Dyke No. 1.—From the engine-shaft cross-cut, S.W. in the 10-fathom level 399 feet, there is a trap dyke (No. 1) ending against the lode on its N.W. side or foot wall; it is about 3½ feet thick, its course is E. and W., and it dips N. about 18 inches per fathom. Between this N. part of the dyke and its S. half, which abuts in like manner against the S.E. side or hanging wall, there is a space of 56 feet. This has the same course, but its dip N. is not more than 12 or 15 inches per fathom.

Dyke No. 2.—There is another smaller dyke composed of close-grained trap; it also abuts against the lode on its N.W. side about 93 feet from the S.W. half of dyke No. 1, or 555 feet from the engine-shaft cross-cut. This dyke is about one foot thick; its course is about N. 70° W., and it dips almost perpendicularly. The other part of this dyke meets the lode on its S.E. or opposite side, at a distance of 18 feet, presenting the same nearly vertical dip, and holding about the same thickness as its counterpart.

Dyke No. 3.—Another dyke, 3 feet or more in thickness, occurs at a distance of 30 feet from the S.E. half of dyke No. 2. As this lode has not yet been driven on this level beyond the dyke, or even entirely through it, it is not possible to state definitely its dimensions, or even its course and dip, though the latter appears to be N., like the other two dykes above described. It would seem to be heaved, but to what extent remains to be seen hereafter.

Adverting to the very different distances to which the two dykes, Nos. 1 and 2, are heaved in this level—viz., 56 feet and 18 feet respectively—it is obvious that the displacement of these divided portions cannot be the result of an exclusively horizontal movement of the walls or cheeks of the fissure filled by the lode, but must be due, in part at least, to a vertical dislocation or shifting. The conditions of the case seem plainly to indicate that the throw of the N.W. side of the fissure has been upward and forward towards the N.E., or that of the S.E. side downward and backward towards the S.W. The exact direction and amount of this oblique displacement of the walls of the lode cannot be computed from the limited data at present furnished by the mine. It seems, however, to have amounted to at least some 3 fathoms in a horizontal direction, and to not less than 12 or 15 fathoms in a vertical one. So heavy a dislocation or throw, when viewed in connection with the great length of the vein, is certainly a very encouraging feature; for it is plain that a crack, whose sides have been so much displaced, cannot pinch itself to very small dimensions, but must remain the same open well-defined fissure which we see it in the mine for a great depth beneath the present workings. Thus the trap dykes, or cross courses, by disclosing to us an extensive displacement of the checks of the vein, confirm in an interesting manner the inferences already derivable from the lode itself, that, compared with the others of its district, it is an injection of mineral matter of more than ordinary regularity, extent, and richness.

EXTENT AND CONDITION OF THE WHEATLEY MINE IN 1853.

The Adit-Level.—The adit or water-level lies at an average depth beneath the surface of about 8 fathoms. Its total length is 1279 feet. Of this space, 410 feet are through red shale from the adit mouth to the lode. From this oblique cross-cut it is 540 feet along the lode to the short cross-cut at the engine-shaft. Thence to the W. whim-shaft it is 194 feet, and beyond this the adit extends 135 feet farther.

The 10-*Fathom Level.*—This level has a total length at the present date, May 1, 1853, of 935 feet from the end of the engine-shaft cross-cut to its present S.W. terminus. It has now been driven 604 feet; and from the same point to its N.E. end it is 331 feet long. It extends, therefore, about 275 feet past the S.W. end of the adit-level.

The 20-*Fathom Level.*—Up to the same date, the 1st of May, this level had been driven S.W. from the engine-shaft cross-cut 465 feet, and N.E. from the same point about 95 feet, being a total length of 560 feet.

Of the Shafts and Winzes.—There are five external shafts and six shorter interior ones—called Winzes by miners—connecting the different levels.

The Engine-Shaft.—The main shaft of the mine, by which all the water is lifted, and a portion of the ore also, has a present depth of 234 feet. It is perpendicular, and enters the gneiss rocks at a point 122 feet S.E. from the lode at the surface. At the adit-level, its distance from the lode, in consequence of this being nearly perpendicular in its upper portion, is still 120 feet; opposite the 10-fathom level its distance is 103 feet, and at the 20-fathom level the space is 76 feet. On the assumption that the present very regular rate of dip of the lode will continue, the shaft will be off from the 30-fathom level—not yet quite reached—about 51 feet, and 26 feet from the 40-fathom, and only 1 foot from the 50-fathom level, a little beneath which it will enter the lode. This shaft is, in regular-dipping gneissic strata, penetrated here and there with injections of granite and sienite.

The S.W. Whim-Shaft, 194 feet S.W. from the engine-shaft, descends in the lode, and has a depth of 174 feet.

The N.E. Whim-Shaft, 311 feet from the engine-shaft, is not in the lode, but in the gneiss rocks, and is so placed that it will cut the lode at the 20-fathom level. Its present depth is about 100 feet.

The Two Adit-Shafts meet the lode at the adit-level, and are only for ventilation. They both are to the N.E. of the engine-shaft: the *first* at 201 feet from it, with a depth of 57 feet; the *second* at 530 feet from it, having a depth of 40 feet.

Of the Winzes within the mine, there are two which descend from the adit-level to the 10-fathom level; one of them situated to the N.E. of the engine-shaft cross-cut, and the other to the S.W. of it.

The other four descend from the 10-fathom level to the 20-fathom level; and of these, one is N.E. of the engine-shaft cross-cut; one lies between this cross-cut and the W. whim-shaft, while the remaining two are to the S.W. of this whim-shaft.

Note.—Subsequently the 10-fathom level has been extended 72 feet, and the 20-fathom level 168 feet.

PRODUCT OF THE MINE IN ORE.

I will now present some notes of the past productiveness of the mine, with my views of its prospective yield.

Good ore has been extracted in stoppings even between the surface and the adit-level: for example, near the engine-shaft cross-cut, for a length of about 40 feet. In the next lift, or between the adit-level and the 10-fathom level, the mine has yielded good ore in three several stoppings: one, N.E. of the engine cross-cut, 40 feet long and 30 feet high; another, just S.W. of the cross-cut, 80 feet long and nearly up to the adit-level, or about 55 feet high; while the third or largest was both N.E. and S.W. of the W. whim-shaft, and had a length of 214 feet, and an average height of some 36 feet.

In addition to this portion already taken out, I would observe that there was in 1853 a mass of ore still above the 10-fathom level, at its extreme W. end, some 35 feet in length.

Between the 10-fathom and the 20-fathom levels there has been very little ore removed as yet, the chief piece of stopping being a little S.W. of the engine-shaft cross-cut. Another mass, about 50 feet long and only 9 feet high, has been taken chiefly from the S.W. of the whim-shaft; and there is yet a third stopping, on the main lode at the S.W. end of the 20-fathom level, 45 feet in length, but carried up at present no more than some 12 feet on an average.

In the portions of the main lode which seem to promise a profitable future yield, there remains some ore above a long stopping near the W. whim-shaft above the 10-fathom level. The ground S.W. of this old stopping is dead, and beyond it we find 36 feet of good stopping-ground to the present end of the level.

From the 20-fathom level on the N.E. end, N.E. of the engine-shaft, occurs a piece of good ground, almost 40 feet long, near the winze S.W. of the engine-shaft cross-cut. This first piece is 66 feet long between the cross-cut and winze. A second piece, beginning 50 feet N.E. of the whim-shaft, and extending for some 250 feet to the present end of this level, though in places quite lean, will pay well for stopping. At the S.W. end of the workings, the lode appears of average richness. On the 10-fathom level there is a cross trap-dyke 3 or 4 feet thick, and beyond this the vein is resumed, but is at present thin, being only just at the dyke. The 20-fathom level is not as far forward within 150 feet. It ends in a very fair lode, and has very recently increased both in size and richness, the ore part being estimated to be 2 feet thick, and to yield 3 tons of ore per fathom.

BRANCHES FROM THE MAIN LODE IN THE WHEATLEY MINE.

An interesting and encouraging feature in this vein, betraying the energy and extent of the rupturing and injecting force, is the presence of several branch lodes which fork off at an acute angle from the main mass, and, for the most part, re-enter it again at a similar obliquity, insulating at the same level, at least, a thicker or thinner mass of the adjoining rock. These enclosed "horses," as the miners call them, are sometimes entirely insulated in certain mines, sometimes only partially so. In the Wheatley Lode, the principal one points off to nothing upwards, and feathers off in both directions horizontally, by the branch veins running into the main lode upwards as well as horizontally; but whether it is thus surrounded in the downward direction cannot be known, since it is growing progressively thicker from level to level descending. That this branch lode will eventually enclose the "horse" in the downward direction, seems altogether probable, from its appearing to be so essentially a true branch shot upward and laterally from the main injection of ore.

The branch veins, as now developed, are—

First, A branch vein or offset from the main lode, which turns out and re-enters it, insulating a horse. This branch at the 10-fathom level is 80 feet between its two junctions with the main lode, and at this level it recedes 9 feet at the thickest part of the horse. The horse contains strings of phosphate and carbonate of lead. This branch joins the main lode about 20 feet above, back of the 10-fathom level. It dips steeper than the main lode, underlying not more than 6 inches in a fathom; for, at 16 feet below the 10-fathom level, the cross-cut to it is 12 feet long, and it will be 20 feet at the 20-fathom level.

This branch yields good ore throughout, chiefly galena. Its average thickness is about 9 inches, and it is richest where the horse is widest, and thins at its junction with the main lode.

Opposite this branch the main lode contains galena and phosphate of lead as on the 10-fathom level—good ore, say about 18 inches in thickness.

There is another branch also on the N.W. or underlying side of the lode, visible in the 10-fathom level, but opened and mined from the 20-fathom level. It has been mined 60 feet from the S.W. point of the horse N.E. to where the workings now are; but it has not been worked round into the lode.

This branch, like the other, is nearly perpendicular, underlying not more than 9 inches per fathom. The horse, at the thickest, is about 12 feet, and at the present end of the workings, 5 feet thick, the branch now approaching the main lode.

The horse is streaked with thin veins, and has chunks and strings of galena, carbonate of lead, &c. There are symptoms of other branches or turn-outs of the vein, some of them on its S.E. side; but these two, here mentioned, are the only ones now working.

These branches, it will be seen, promise to contribute quite a considerable auxiliary amount of ore to that derived from the main lode, and they deserve to be very carefully sought and pursued.

Of the other or productive half, a careful study of the Wheatley Mine induces me to believe that the average yield in good ore, calculated to the square fathom, is from $1\frac{1}{4}$ to $1\frac{1}{2}$ tons.

It is in the power of any person, from these data, and from the other elements of length and depth already presented, to estimate for himself, on the reasonable assumption of a permanency in the averages I have ventured to give, the total future yield of the whole lode, embraced between the limits within which it has been opened, and is now being wrought, in the Wheatley and Brookdale mines.

In support of the general accuracy of my estimate of February 1852, of the quantity and aggregate value of the ore then accessible in the mine, I beg leave to mention, that I learn from the books of the Company, that the quantity of marketable ore actually extracted from those workings and sold, proved to be almost exactly what I at that time computed it, as it lay unbroken in the mine.

I cannot conclude this description on the Wheatley and Brookdale Lode, and the two mines recently wrought in it, without expressing, in distinct terms, my conviction, that the whole vein, as far as opened, holds out a good promise of permanency and richness, or, in other words, of fair remunerative profit, if efficiently and frugally wrought. But to work it to the best efficiency, which in mining is the only true economy, it will be indispensable, I conceive, to drain the lode of the chief part of its water by a powerful pumping-engine and central shaft, stationed at some point between the present Wheatley and Brookdale engine-shafts, competent to relieve both of these mines of their main influx of water, and to make the vein accessible through a greater length and depth than can possibly be commanded by the existing comparatively feeble engines.

THE PRESENT EXTENT OF THE BROOKDALE MINE.

The Brookdale Lode, or, more strictly, the Brookdale end of the Wheatley Lode—for every indication implies that the two mines are situated on one and the same metalliferous vein—has been already sufficiently described in referring to the features of the whole under the name of the Wheatley Lode. There would seem to be very little room to doubt that this assumed continuity of the vein really exists; for though both the Wheatley and the Brookdale portions, in certain sections of their length, deviate considerably from the direction of the line joining the most distant shafts, yet the vein appears to return again to this general average course, the departures being neither very wide nor long. The same undulation in its course is noticeable at the Brookdale end which we witness in the Wheatley portion. Though the actual distance on the lode between the S.W. end of the present workings in the Wheatley Mine, and the nearest positively proved point in the Brookdale Mine, is about 1308 feet, yet the coincidence in direction in the surface vein-stones, and in the ores, and all their accompaniments, is so striking as to convince every attentive observer that the two mines are seated upon one and the same lode. Referring to the general statements given in the preceding sketch of the geological and mineral features of this vein, and its relations to the other veins of the district, I proceed to offer a few notes and observations respecting the Brookdale Mine.

The length of lode opened by the adit-level is about 456 feet, but there are decided indications on the surface along the course of it, even a few hundred feet beyond the point at which the adit at present terminates, that the vein still continues. The lode through much of the Brookdale ground or sett, outcrops near the bed of the little transverse valley which descends N. from a range of higher land; as a consequence, the adit-level is not deep beneath the surface, being nowhere lower than 6 fathoms, and, on an average, only 4 fathoms.

In this adit-level, the lode is stained with spots of carbonate and phosphate of lead, and with galena, for a length of about 400 feet, or within some 60 feet of the end of the level. The gossans, vein-stones, and ores of the Brookdale Mine are identical with those of the Wheatley, and it exhibits in its hanging wall precisely the same variety of soft white felspar and quartzose granite which distinguished the same wall of the latter, and which I have so very often noticed to be the accompaniment of our richest metalliferous veins.

Above this adit, several tons of marketable ore were procured at no greater depth than some 20 feet; and below this level the vein steadily improves in richness in the shaft.

On the whole, the indications of a productive vein in the lower levels of this mine seem encouraging; but to open the lode satisfactorily, a powerful pumping-engine is indispensable. The position of the vein so near the bed of a ravine will render this mine a wet one; and although the present excellent engine of 60-horse power will be competent to the drainage of the first upper levels, it can never grapple with the burden of water to be lifted when the workings grow deep and extensive.

MINERAL VEINS AND METALLIFEROUS DEPOSITS OF THE GNEISSIC REGION N. OF THE CHESTER COUNTY VALLEY.

GRANITIC AND TRAPPEAN DYKES.

Penetrating the gneiss in different parts of the district are many injections of various kinds of granite, greenstone, and augitic trap, and other true igneous rocks. Throughout the region the injections of granite consist, for the most part, of a coarse binary mixture of white opaque felspar and quartz, showing a tendency to decomposition. This rock occurs in narrow dykes with nearly parallel walls, and in ramifying veins. Sometimes these cut the beds of gneiss nearly perpendicularly, while, in other instances, they partially conform to its bedding, or die out in more or less tortuous branches among its contorted layers. A somewhat common variety of the granite consists of quartz, greenish semi-translucent felspar, and a small proportion of dark hornblende. These white felspathic granites seem most to abound in the S. half of the district, where, as we have already seen, the prevailing constitution of the gneiss approximates to that of the dykes. In the N. half of the region we meet with a relatively greater proportion of intrusive rocks containing a predominance of hornblende, augite, and the minerals which usually go with these; and it is worthy of note that in this quarter the stratified crystalline rocks themselves include a commensurately greater amount of the same minerals.

PREVAILING DIRECTION OF THE GRANITE DYKES.

Though these intrusive rocks observe various directions, their prevailing course is N.E. and S.W., or still more generally, perhaps, N. 55° or 60° E., and their dip, where not perpendicular, is, for the most part, steeply towards the S.E.

TRAP DYKES.

The trappean dykes of this district are generally narrow, and consist for the most part of a closely crystalline, fine-grained, bluish, hornblendic trap-rock. They run in nearly all directions, but their usual course is E.N.E. and W.S.W. They are part, in fact, of that extensive system of trappean injections which embraces the whole belt of country S. of the chain of the South Mountains or Highlands; or, more comprehensive still, includes, we may say, the entire Atlantic slope from New England to the Southern States, defining this as bounded on the N.W. by the chain of the Green Mountains and Hudson Highlands, the South Mountains and the Blue Ridge.

Small trap-dykes are common in the townships of Vincent and East and West Nantmeal. The two high hills near Warwick's furnace consist of trap—the largest mass of this rock in the township.

METALLIFEROUS VEINS.

Besides the above classes of intrusive rocks, and some others, too few and local to be referred to in this place, there occur, in the region before us, several interesting injected veins, or groups of veins, of metalliferous and other minerals. Some of these have been objects of mining enterprise, and have already well repaid the investments upon them, while the commercial value of the chief number yet remains to be tested.

These metallic veins are distributed in two principal neighbourhoods or local mining districts, distinguished from each other by important general differences in the nature of the metallic ores and their associated minerals. One of these districts is that narrow belt of the gneissic rocks which lies nearly in the prolongation of the Welsh Mountains on the N. branch of French Creek. The predominant metalliferous injections are veins or lodes of magnetic oxide of iron; but other mineral lodes, especially one or two, bearing ores of copper and zinc, likewise occur here. I will here introduce the following brief description of such of these as have hitherto been explored or mined.

KNAUERTOWN IRON AND COPPER VEINS.

The most Eastern or first vein of this belt which meets our attention is that of Crossley's iron-ore pits, about one mile N. of Knauertown. These pits are no longer wrought, and the true geological character of the vein or veins in which they were sunk it is now difficult to ascertain, inasmuch as they are abandoned, and, indeed, were never very extensively pursued. Sufficient indications prevail, however, and enough information is accessible in the neighbourhood, and through persons at one time commercially interested in the success of the mines, to satisfy me that these several pits all pertain to an irregular lode, or a chain of closely-connected lodes, of igneously-derived magnetic oxide of iron. This vein occurs between walls of gneiss rock, in a low ridge just E. of the N. branch of French Creek. Near the extreme Western end of this little ridge, the ore, when uncovered to the day, presented a mass in the form of a large expansion of a vein of several feet thickness; but upon sinking the mine in it, this promising body of ore rapidly thinned down, and was even almost cut out by a contraction of its walls. Well-formed octahedral crystals of the magnetic iron-ore are very abundant in this vein; and indeed this variety is rather characteristic of the iron lodes of this N. belt of gneiss. The absence of regularity in the vein, and the necessity of providing steam-power for the deeper prosecution of the mine, caused its suspension some years ago; but it is not improbable that it will be resumed at a future day, since the work done was not without encouragement.

ELIZABETH COPPER MINE.

Immediately adjoining the before-mentioned vein of magnetic ore of iron, there exists a very interesting mineral vein, known sometimes as the Knauertown Copper Lode, or that upon which is seated the Elizabeth Copper-mine. This injection, likewise, occurs in the gneiss; but a granitic vein, composed chiefly of felspar and augite, forms its actual wall on the S.; the vein itself, observing a course nearly parallel with the strike of the strata into which it has been injected, consists largely of crystallised calcareous spar, dispersed through which occurs well-crystallised oxide of iron, and many brilliant octahedral crystals of the sulphuret of iron, and likewise some copper pyrites. The copper ore, diffused feebly throughout the calcareous spar, is most abundant next the N. wall of the vein. Measured transversely on a horizontal line, the dip being steeply N., the width of this whole vein or bed of spar is not less than 45 feet; an engine-shaft descends upon the lode a depth of 140 feet; and there is an interior underlay-shaft, descending from the bottom of the main shaft, 45 feet deeper. From the bottom of this latter pit, a cross-cut runs S. 28 feet, and another to the N. 22 feet; while a drift has been carried along the lode E. a distance of 55 feet; and this is the present extent of this small experimental copper-mine, the active prosecution of which was suspended in May 1854, whether to be resumed or not I cannot say.

It deserves to be here noted that these mineral veins are situated a short distance N. of a very thick dyke, or wide belt of trap-rock, which extends along the N. side of the narrow tongue of middle secondary red sandstone which insulates the metalliferous belt of gneiss from the main gneissic region S.

STEEL'S IRON-ORE PITS.

The next metalliferous vein of the tract, of any note or present promise, is one situated about half a mile N. of the village of St Mary's. This has not been wrought for many years; and very little precise information is derivable respecting it, beyond that furnished by observation of the old surface-diggings, and by vague tradition. There is obviously here a true lode or vein of magnetic iron-ore, containing much of the octahedral variety. A wide surface-pit and an adit suggest that the ore was in some abundance here, and such is the tradition of the neighbourhood; but what the precise geological characters of the vein may be, or what promise it may have held out of some day proving profitable, there are no sufficient data for determining. It occurs in gneiss, a little N. of a heavy dyke of trap-rock, and seems to have an E. and W. direction.

HOPEWELL FURNACE ORE-PITS.

Proceeding Westward along this strip of gneiss, the next and last important mineral injection which we meet with is that of the iron mines of Hopewell Furnace. These are situated about one and a half miles N.W. of St Mary's, or the Warwick Iron Mine, and near the N. edge of the belt of gneiss, where it is margined by a range of white Primal sandstone, forming a spar in prolongation of the Welsh Mountains, called Thomas's Hill. This mine has been wrought for very many years. There are in all four ore-pits here, only two of which, however, are now wrought: both of the new pits, or those at present worked, are drained by one engine-shaft. This ore is a highly crystalline variety of the magnetic oxide of iron, presenting many specimens of beautiful octahedral crystals. The ore is in two veins, both dipping at a moderate angle of about 30° towards the N.W. One of these, the undermost, varies in thickness from 15 to 25 feet; the other overlying vein has an average thickness of some 7 feet. A thick dyke of close-grained grey trap-rock cuts and partially shifts the ore. Its course is about S.E. and N.W., while that of the veins of iron ore is N. about 65° E., or, as usual, nearer E. and W. than the trappean dyke. Unfortunately, the engine-shaft has been sunk thus far almost entirely within the trap-rock, a mistake entailing great delay and much unnecessary expense. It is designed to intercept the veins or beds of ore, at a good depth below the surface, in their dip to the N.W.

WARWICK IRON MINES.

To avoid dispersing unnecessarily our descriptions of the mineral veins and ore localities connected with the gneissic district, we will pass in the next place to those which lie contiguous to the insulated belt of gneiss on the N. border of the region, without adhering too rigorously to principles of classification. This brings us to treat of two or three localities along the N. margin of the main district of gneiss, but compels us to introduce a description of some ores and minerals, which, though in some respects of igneous origin, are not wholly so. There are, however, in this tract, some genuine intrusive lodes, and to the best developed and chief of these we will proceed first.

LEIGHTON IRON-ORE MINE.

A little south of the village of St Mary's, just outside of the margin of the shallow deposit of the red sandstone, and its fringing lower layers of conglomerate, is situated the Leighton Iron Mine. A large surface-excavation, embracing two veins of igneous magnetic iron-ore: these range N.E. and S.W., and to the N.W., at an angle of about 33°. The overlying vein, when first opened at the surface, measured 15 feet transversely, but, pursued for 25 feet below the water-level towards the S.W., it has dwindled to a thickness of only 15 inches.

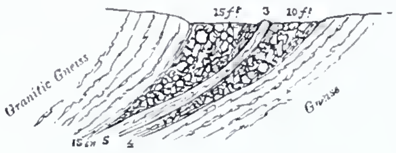


Fig. 571.—Leighton's Iron Mine, Warwick, Chester County.

The other, or lower vein, distant from the first from 3 to 5 feet, was 10 feet thick at the surface, and declined in size to 4 feet. The mining and exploratory shafts together extend along the vein about 500 yards, but the actual excavations in the ore do not cover a length of more than 200 feet. The dip of the open cut in the ore is about 40 feet.

From this mine the whole quantity of ore removed before its abandonment was about 20,000 tons.

The accompanying little section (Fig. 571) illustrates the form and position of these veins.

WARWICK IRON-MINE PROPER.

This extensive and interesting body of iron ore, situated just S.E. of St Mary's Episcopal Church, is in reality not a genuine lode or igneous intrusive vein, though the ore derives some of its characters from intrusive igneous action, but it is a bed or deposit at the base, or very near the base, of the middle secondary red sandstone, which here laps upon the gneiss. The explored extent of this bed, hitherto penetrated only near its outcrop, or where the overlying strata are shallow, is already very great, amounting to many acres. The ore-deposit observes everywhere a very gentle dip, and seems to undulate in two or three waves across the tract which includes it. A somewhat conspicuous anticlinal change in the dip occurs to the S. and S.W. of the present main engine-shaft by which the mines are dried, and there is every indication that the ore basins both S. and N. of this saddle. Though the basin to the S. of it is intersected, and the ore in one place cut off or thrown out to the surface, by the intrusion of a wide dyke of trap-rock, there is strong reason to infer that the ore occupies a comparatively wide, though perhaps shallow basin, N. and N.E. of the engine-shaft.

Besides this intrusion of trap, there seem to exist here injections of serpentine and other mineral matters, and at one point, just by the S.W. margin of the ore bed, there exists a very singular intrusion of mineral matter penetrating the ore, and altering, in a remarkable manner, the conglomeritic layers which here constitute the S.E. border of the red-sandstone formation. This rock is greatly baked and changed in aspect, includes numerous spheroidal bunches of segregated crystalline mineral matters—some of them in the form of hollow geodes—and is intersected besides with numerous strings, or little veins. In these spheroidal nests occur beautiful linings of crystallised epidote and other minerals, and bunches of large crystals of the fine variety of garnet called Melenite. The list of the minerals occurring here is not extensive. The conditions under which they present themselves are such as strongly to impress the geological observer with the notion of their having been introduced chiefly in a vaporous state, or by sublimation, for in many of these hollow spheroids we can detect no connection whatever between the interior or even the exterior walls of the geodes, and any external veins or filaments of injected matter, such as any other theory would demand, for the introduction of the materials of the crystalline minerals here so curiously insulated.

The bed of iron ore for which this locality is chiefly noted is of very variable thickness, fluctuating from 1 or 2 to 9 or even 17 feet. As illustrating the general levelness of this undulating deposit, it may be stated that in no place has it been required to sink deeper than about 60 feet to reach the ore, while generally the covering is so thin that the ore is conveniently procured by merely stripping off a thickness of a few feet or yards of loose disintegrated rock. The average richness of this ore may be stated at about forty-five per cent of metallic iron, though much of it exceeds fifty per cent. It is somewhat sulphurous, and when care is not employed in selecting it for smelting, and in the after-processes, it tends to produce a hot-short or red-short iron, but when carefully manufactured it yields an excellent metal. The annual product of the Warwick Iron Mines for fifteen years was not less than 4000 tons, and the average yield for the past twenty years has been 6000 tons. In the year 1853 the amount mined reached 12,000 tons. These ore-pits have been wrought for the last 120 years, and there would seem to be at present really more ore within sight than there has ever been before, at any one time. The present average cost of mining this ore is about one dollar and fifty cents per ton.

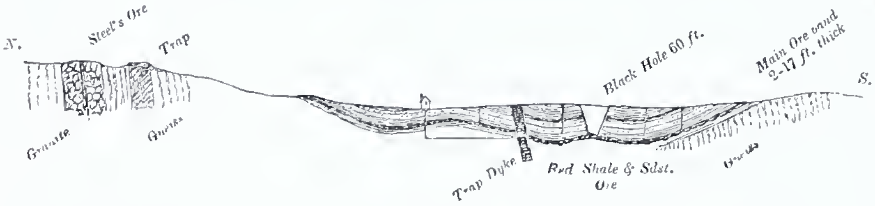


Fig. 572.—Ore Ground at St Mary's, Old Warwick Pits, Chester County.

Annexed is a little section—not the result of any critical measurements, however—of this valuable and interesting mass of iron ore.

This ore is intermediate in its physical characters and aspect between the true brown hæmatite and the magnetic oxide of iron. As, on the view of its having been originally a hæmatite, but subsequently altered by igneous action, we might naturally anticipate, those portions of it which have undergone the highest degree of metamorphic influence are of a grey colour, quite crystalline, and partially endowed with magnetic force, whereas the less altered parts are nearly in the condition of a compact closely-cemented hæmatite. Minutely interstratified with this ore, there occurs more or less earthy matter, apparently lamina of indurated slate or shale; and when the layers of this rock are thick, and they disperse the ore, they interfere materially with the economical prosecution of the mine. This slaty or earthy matter tends furthermore, by intimately mixing itself in with the finer granular ore, seriously to reduce the richness of the mingled mass in iron.

KNAUERTOWN IRON MINE.

A little N. of Knauertown, just on the S. margin of the tongue of red sandstone which there divides the N. belt of gneiss from the principal district of that rock, there occurs a small deposit of iron ore precisely identical in geological position with that of the Warwick Mines, and very similar to it in aspect. A few shafts have been sunk in quest of this ore, under the hope that it might prove abundant enough to be a source of profit, but no sufficiently large deposit has been reached to justify anticipations or encourage any further mining. The indications of igneous action, though not entirely wanting here, betray much less of the subterranean energy than was manifested in connection with the ore at the old Warwick Mines.

OTHER MINERAL VEINS IN THE NORTHERN GNEISSIC DISTRICT.

Near the junction of Beaver Creek with French Creek, or a short distance to the S.W. of Pughtown, there is a vein of impure plumbago on the farm of Jesse Hawley. It occurs between beds of gneiss, is about 3 feet in thickness, and dips with the strata to the S.E. about 45°. The plumbago is pulverulent, and mixed somewhat with foreign matters, especially oxide of iron, oxide of manganese, and some of the minerals of the gneiss, in a state of disintegration. The excavation exposing it is a very superficial one, being merely a drift, of the length of a few fathoms, penetrating the vein at the water-level. After being mined, the material is broken, screened, and washed, when it is packed and sent to West Chester, there to be converted into a fireproof mineral paint for railroad cars, houses, barns, and other structures. This paint is prepared dry, and also ground in oil. It has been found very useful in resisting atmospheric exposure, though it has been employed as yet to a very limited extent

OLD COPPER MINE, ON COPPER MINE RUN, IN BATH TOWNSHIP, IN LANCASTER COUNTY.

A mineral locality of some note, but of small mining interest at present, is that of the Old Copper Mine in Lancaster County, on the N. margin of the long narrow belt of gneiss, at the S. foot of the Mine Ridge. The vein here, of the ancient workings of which very little is at present known, contains iron pyrites, copper pyrites, and a sulphurate of iron, and nickel.

This copper mine was originally opened for copper, but very little ore of this metal has ever been extracted. The lode ranges nearly E. and W., and its ascertained length is about 60 yards, though probably it is actually greater. The vein is nearly perpendicular, dipping very steeply to the S. On its N. side the wall is a fine-grained trap-rock; on its S. side a crystalline hornblende. The lode itself is from 10 to 12 feet thick. There are two levels, one about 10 fathoms, and the other 17 fathoms, below the surface, but the ore is not reached until about 7 fathoms are gained. This ore is very poor in copper, not yielding more than from three and a half to four and a half per cent, but the mine seems to promise somewhat better as it advances. The ore is conveyed to Canton, New Jersey, to be smelted there, though very little has yet been taken.

LOCALITIES OF WELL-CHARACTERISED CRYSTALLINE MINERALS WITHIN THE GNEISSIC DISTRICTS OF PENNSYLVANIA.

The following lists of well-defined mineral species, suitable for cabinet specimens, ranged under the localities where they can be found, have been derived chiefly from the latest edition of Professor James D. Dana's excellent *System of Mineralogy*, to the descriptive text of which work I must refer the reader for more copious information respecting the minuter characters of the minerals, and their precise positions. The memoranda were mostly furnished, as Professor Dana states, by Messrs Williams and Seal, of Chester County, two well-informed local mineralogists, who have explored the mineral neighbourhoods of Southern Pennsylvania with much zeal and care. We desire here to return them our own thanks for useful notes guiding us to the places, and the mineral species mentioned.

The catalogue of Easton minerals is due chiefly to Dr Swift of that town, while other memoranda, relating to other places outside of Chester and Delaware counties, are the results of our own personal observations.

MINERALS IN THE SOUTHERN GNEISSIC DISTRICT.

Philadelphia.—In the Southern range of true gneiss, *laumonite*, *garnet*, *tourmaline*, and *mica*, occur on the Schuylkill, near the foot of the old inclined plane; and yellow *uranite*, a fourth of a mile from the Suspension Bridge. In the same belt, at Frankford, occur *garnet*, *staurotide*, and *iron pyrites*.

Delaware County.—Within the S. range of the gneiss are to be found, in

Aston Township, near Village Green, *amethyst*, *corundum*, *emerylite*, *staurotide*, *sillimanite*, *black tourmaline*, *pearl mica*, *asbestos*, *anthophyllite;* and near Tyson's mill, *garnet* and *staurotide;* and at head of Peter's mill-dam in a brook, *garnet*, resembling *pyrope*.

Birmingham Township.—At Bullock's quarry, *zircon*, *bucholzite*, *fibrolite*, *nacrite*.

Chester Township.—*Amethyst*, *black tourmaline;* in Burk's quarry, *beryl*, *black tourmaline*, *felspar*, *manganesian garnet*, and *cryst. pyrites;* on Chester Creek, at Carter's, *molybdenite*, *molybdic ochre*, *copper pyrites*, *tourmaline*, *kaolin;* at Little's quarry, *brown garnets*, *tourmaline;* and near Henvi's quarries, *amethyst* in *geodes*.

Chichester Township.—Near Trainer's mill-dam, *beryl*, *tourmaline*, *cryst felspar*, *kaolin;* and on W. Eyre's farm, *tourmaline*.

Concord Township.—On Queen's Creek, *garnets*, resembling *pyrope*, *bucholzite*, *mica*, in hexagonal prisms, *beryl*, *actinolite*, *agthophyllite*, *fibrolite*, *rutile*, in capillary crystals in the cavities of cellular rose quartz.

Darby Township.—In a boulder, *kyanite*, *zoisite*; and near Gibbon's, *garnets*, *staurotide*.

Leiperville.—*Beryl*, in granite; in Leiper's quarries, *beryl*, *tourmaline*, *apatite*, *garnet*, *cryst. felspar*, *mica;* at Morris's Ferry, *kyanite*, *sillimanite*, *apatite*, *red garnet*, and *mica;* at Hill's quarries, *chabazite*, *stilbite*, *zeolite*, *epidote*, *sphene*, *albite*, *calcite*, *cryst. pyrites;* near Leiper's church, on the edge of a wood, *andaluzite*, *apatite*, *tourmaline*, *mica*, *and grey kyanite*.

Springfield Township.—*Andalusite;* on Worrell's farm, *tourmaline*, *beryl*, *ilmenite (?) garnets;* on Fell's Laurel Hill, *beryl*, *garnet;* near Beatty's mill, *staurotide apatite;* near Lewis's paper-mill, *tourmaline*, *mica*.

Chester County.—The only localities in this county, belonging seemingly to the true gneiss formation, are as follows:—

Pennsburg Township.—*Brown garnets;* on Cloud's farm, near Pennsville, *mica*, in hexagonal prisms, from one quarter to seven inches in diameter

Kennet Township.—On Gregg's farm, *actinolite*, *brown tourmaline*, *brown mica*, *epidote*, *tremolite*, *seapolite*, *arragonite;* at Peirce's paper-mill, *zoisite*, *epidote*, *sunstone*, *chabazite*, *stilbite*, *labradorite;* on R. Lamborne's farm, *chabazite* in small brownish-yellow crystals (rare), and *zeolite;* and at Gauss's corner, *epidote*.

Goshen Township.—At water-works, *zoisite;* at Jeffrey's Ford, *zircon*.

MINERALS IN THE MIDDLE GNEISSIC DISTRICT OCCURRING IN THE GENUINE OR OLDER GNEISS.

Wheatley Lead Mine, near Phœnixville.—The Wheatley Lode is the best developed, richest, and most abundant in crystalline minerals of the group of veins to which it belongs. A list of its ores and minerals has been already given.

Chester County Lead Mine, adjoining the Wheatley Mines.—*Allophane*.

Gap Mine, near Mine Ridge.—*Magnetic pyrites*, containing *nickel*, *copper pyrites*, *actinolite*.

Knauertown, N. of Pughtown.—*Graphite*, *sphene*, *cryst. magnetic iron;* in Chrismard's iron-mine, *zircon*.

Keim's Iron Mine, near Knauertown.—*Flos-ferri*, *pyroxene*, *micaceous iron-ore*, *aplome*, *actinolite*, *yellow octahedral pyrites*, *copper pyrites* in tetrahedrons, *red garnet*, *malachite*, *hornblende* (var. byssollite).

Steel's Iron Mine, half a mile N. of village of St Mary's.—*Magnetic iron-ore* in octahedral crystals, *micaceous iron ore*, *coccolite*.

Hopewell Furnace Iron Mine.—Beautiful specimens of octahedral crystals of *magnetic oxide of iron*.

South Coventry Township.—On farm of Jesse Hawley, near junction of Beaver and French Creek, *plumbago*.

MINERALS OF THE NORTHERN GNEISSIC DISTRICT, OR OF THE SOUTH MOUNTAINS AND THEIR SPURS BETWEEN THE DELAWARE AND SCHUYLKILL.

The genuine gneissic rocks of this range include but few mineral localities; the interesting points near Easton from whence so many beautiful cabinet specimens have been derived, belong to the Primal slate and Auroral limestone formations, and their contents will be mentioned under these heads, in their proper places, later in this chapter.

Chestnut Hill, N. of Easton, consisting of gneiss, but flanked by higher formations, contains several crystalline minerals already mentioned in the text, some of which belong to its gneissic rocks.

Near *Bethlehem*, but in the South Mountain, there occur, in a sienitic gneiss, *allanite*, *magnetite*, *epidote*, *brown garnet*, *black spinel*, *and tourmaline*. In the same range, near *Allentown*, occurs *magnetic iron-ore*.

MINERALS OF THE METAMORPHIC PRIMAL STRATA, AND OF THE MIDDLE RANGE OF THE SOUTHERN GNEISSIC DISTRICT, POSSIBLY THE SAME FORMATION UNDER MORE EXTREME METAMORPHISM.

Philadelphia, Mica-slate range:—

Chestnut Hill.—*Mica*, *serpentine*, *dolomite*, *asbestos*, *nephrite*, *talc*, *tourmaline*, *sphene*, *apatite*, *tremolite*.

Germantown.—*Mica*, *apatite*, *felspar*, *beryl*, *garnet*.

Banks of Wissahickon.—*Actinolite*, *garnet*, *staurotide*.

Manayunk Tunnel.—Stilbite, chabazite.

Delaware County :—*Marple Township.—Tourmaline ;* on A. Worrell's farm, *andalusite, tourmaline ;* near Palmer's mills, *beryl, tourmaline, actinolite, amethyst.*

Edgemont Township.—Rutile in quartz, *amethyst, oxide, manganese, cryst. felspar.*

Mineral Hill.—Corundum, aventurine, felspar (sunstone), *chatoyant felspar* (moonstone), *actinolite, green coccolite, green felspar, chromic iron, cryst. green quartz, ferruginous quartz, hydrous asbestos, anthophyllite, brown garnet, magnesite, marmolite, bronzite, chalcedony, limonite, labradorite, floatstone, red garnet, beryl, serpentine.*

Providence Township.—At Blue Hill, *serpentine, cryst. green quartz* in *green talc, asbestos, talc, anthophyllite, actinolite, hydrous anthophyllite ;* on Hunter's farm, *amethyst* (one fine crystal weighed more than 7 pounds), *andalusite.*

Chester County :—*Birmingham Township.—Kerolite, amethyst, quartz, serpentine.*

East Marlborough Township.—Epidote, and nearly *white tourmaline.*

West Chester, 3 miles S. of town.—*Clinochlore, phlogopite.*

ALTERED PRIMAL SLATES.

Montgomery County :—at *Gulf Mills.—Limonite, garnets, chromic iron.*

Delaware County :—*Radnor.—Garnets, marmolite, deweylite, serpentine, chromic iron, asbestos, magnesite.*

Chester County :—*Willistown Township.—Magnetic iron, chromic iron, actinolite.*

West Goshen Township.—Amianthus, asbestos, precious serpentine, cellular quartz, jasper, chalcedony, drusy quartz, chlorite, marmolite, dolomite, cryst. carb. magnesia, chromic iron, magnetic iron.

West Chester, 1½ miles N. of town.—*Hydro-magnesite, clinochlore, brucite in serpentine* ; 2 miles W., *zircon ;* 1½ miles N.W., *pitch-black allanite.*

Unionville vicinity, 1½ miles N.E. on Serpentine Barrens.—*Corundum* massive and cryst. in *albite,* also loose on surface, sometimes coated with *gibbsite* and *steatite ; talc, green tourmaline, asbestos, hydrate of magnesia, yellow beryl* (rare), *serpentine, brucite, magnetic iron, octahedral iron, chromic iron, hydrated oxide of nickel* on *chrome, quartz crystals, green quartz, actinolite, chlorite, picrolite, clinochlore* in cryst. *diallage, granular albite, adularia, oligoclase, halloysite, margarite, euphyllite, allanite, hematite, chalcedony, cornelian, jasper, pechkohlite ;* half a mile S.W. on Webb's farm, *serpentine, chromic iron ;* 2 miles S.W., at Pusey's sawmill, *zircon, rutile ;* 1 mile S., bright yellow and nearly white *tourmaline, orthoclase* (*chesterlite*), *albite ;* near Marlborough Meeting-house, *epidote, serpentine, acicular black tourmaline,* in white quartz ; 1 mile W., near Logan's quarry, *staurotide, kyanite, yellow tourmaline.*

East Bradford Township.—On Minorcus Hill, green, blue, and grey *kyanite, apatite, allanite ;* on Taylor's farm, *sphene, cryst. smoky quartz ;* on farms of Jones, Price, Sharpless, and Entriken, *amethyst ;* near Strode's mill, fine *talc, asbestos, magnesite, marmolite, garnets, lithomarge ;* near Hooper's sawmill, *epidote, asbestos ;* on Osborne's Hill, *sphene, manganesian garnet, wad, tourmaline, actinolite, anthophyllite, felspar, fetid calcite ;* near Black Horse Inn, *rutile.*

Chester and Lancaster Serpentine Barrens, near the State line.—The Serpentine belt and its borders contain, at Scott's Chrome Mine :—*Chromic iron, foliated talc, marmolite, serpentine, and chalcedony.*

Near *Texas*, at Wood's Chrome Mine :—*Emerald-nickel, pennite, kæmmererite, millerite, baltimorite, chromic iron, marmolite, picrolite, hydro-magnesite, brucite dolomite, cryst. magnesite, calcite, serpentine ;* at Low's Mine, *hydro-magnesite, brucite, picrolite, magnesite, chromic iron, talc, emerald-nickel, serpentine, baltimorite :* on Boice's Farm, N. of village, in soil, *cryst. pyrites, anthophyllite, marmolite, magnesite ;* near Rock Spring, *chalcedony, cornelian, moss agate, green tourmaline* in talc, *titanic iron, cryst. magnetic iron* in chlorite ; at Reynolds' Mine, *calcite, talc, picrolite.*

Parkesburg.—In Primal white sandstone of N. and S. valley hills, much *black tourmaline*, often in dislocated crystals ; in soil for 7 miles along S. edge of valley, *rutile.*

Little Brittain Township.—Anthophyllite.

The metamorphic Primal strata embrace several important very extensive deposits of brown iron-ore, in some of which there occur magnetic oxide of iron, and even perfect crystals of the octahedral form. The chief part of these accumulations of half hæmatitic, half magnetic ore, belong either to the very upper portion of the upper Primal slate formation adjoining the base of the Auroral limestone—that is, to the first alternating limestone and slate beds constituting the transition from the one series to the other ; or to the very base of the upper Primal slate, where it rests on the Primal white sandstone. The Cornwall ore occurs high in the Primal slate ; that of Jones's mine in Berks County, in this slate, just below its contact with the limestone ; some of the deposits of Safe Harbour on the same horizon ; others rather lower down, more nearly on the horizon of the Cornwall ore ; while the great Chestnut Hill deposit is at the very base of this upper Primal slate, where it reposes on the Primal white sandstone.

Berks County.—At Jones's Mine, near Morgantown, *green malachite! cerusite, chrysocolla! octahedral* and *dodicahedral magnetic iron, iron pyrites, copper pyrites.*

York County.—*Calc spar ; cryst. smoky quartz ; cryst. pyrites ;* in Peachbottom slate-quarries, *wavellite.*

Northampton County :—*Easton.—Quartz* (large crystals) ; *augite* (at the Bushkill, Chestnut Hill) ; *zircon* (in talcose slate at Larrich's, Chestnut Hill) ; also *plumose mica.*

LOCALITIES OF MINERALS ASSOCIATED WITH THE AURORAL LIMESTONE.

SOUTHERN METAMORPHIC DISTRICT.

Bucks County.—Near *Attleboro'*, at Vanartsdalen's limestone quarry, *sahlite*, *scapolite*, *sphene*, *green coccolite*, *graphite*, *green mica*, *tabular spar*, *rutile*, *actinolite*, *augite*.

Chester County :—*Pennsbury Township.*—At Harvey's limestone quarry on the Brandywine, *chondrodite ;* at Burnett's lime quarries, *sphene*, *diopside*, *augite*, *coccolite ;* at Mendenhall's quarry, *carb. strontia ;* at Brinton's mill on Brandywine Creek, *chondrodite*.

New Garden Township.—At Nevin's limestone quarry, *brown tourmaline*, *scapolite*, *brown and green mica*, *rutile*, *arragonite*, *kaolin*.

London Grove Township.—In Jackson's limestone quarry, *yellow tourmaline* (rare), *fibrous tremolite ;* at Pusey's quarry, *rutile*, *tremolite*.

West Bradford Township.—Near A. Jackson's limestone quarry, *green kyanite*, *rutile*, *scapolite*, *iron pyrites ;* near Marshall's mill, *chromic iron*, *serpentine ;* at Poorhouse limestone quarry, *rutile*, in brilliant crystals, *cryst. calc. spar*, *cryst. dolomite*, *zoisite :* on quartz, *talc* (cryst. or dolomite), *chesterlite* (in fine crystals on dolomite).

Unionville Vicinity.—Two and a half miles S.W. of Unionville, in Bailey's limestone quarry, *fibrous tremolite*, *mussite*, *kyanite*, *margarodite ;* on farm of Bailey and Brothers, *yellow*, *green*, *and white tourmaline*, *chesterlite ;* at Edward's limestone quarry, *purple fluorspar*, *rutile ;* in limestone quarries near Doe River village, *scapolite*, *rutile*, *tremolite*. In this range of limestone quarries, extending from near the Red Lion Tavern South-westward, parallel with and S. of the street road, occur *rutile*, *yellow tourmaline*, *tremolite*, *chesterlite*, *&c.*

Montgomery and Chester Valley, in Auroral limestone.—At Henderson's marble quarry, *calc spar ;* one mile N., on railroad, *cryst. quartz in geodes ;* at Spring Mills, *cacoxene*, *lepidokrokite*, and *spathic iron ;* 5 miles W. of Penningtonville, near Bear Tavern, in crystallised limestone, *rutile* and *bitter spar*.

MIDDLE METAMORPHIC DISTRICT.

Lancaster County :—*Peequa Valley.*—Eight miles S. of Lancaster, *argentiferous galena* (250 to 300 ounces of silver to the ton); 4 miles N.W. of Lancaster, on railroad, *calamine*, *galena*, *blende*.

Chester County :—*East Nantmeal Township.*—S.W. of Chrissman's Ford, *graphite*, *augite*, *sphene*.

NORTHERN METAMORPHIC DISTRICT, OR SOUTH MOUNTAINS.

Lehigh County.—In Saucon Valley, near Friedensville, occur *calamine* (promises to be a valuable mine), *lanthanite*, *crystallised quartz*, *malachite*, *pyrolusite* (*wad*).

Northampton County.—Hill N. of Easton, *cellular quartz* (pseudomorphous), *pyroxene*, *coccolite*, *green augite*, *sahlite* (opposite the Spring, Jersey side), *white fibrous tremolite*, *lead-coloured tremolite*, *glassy tremolite*, *actinolite*, *radiated actinolite*, *glassy actinolite*, *asbestos*, *nephrite*, *jade*, *reddish jade*, *chondrodite* (opposite Wolf's quarry, on Jersey side of river), *mica*, *silvery mica*, *saussurite*, *green talc*, *tourmaline*, *serpentine* (cryst.), *serpentine with carb. lime* (a kind of verde-antique); at Spring, *chlorite*, *calamite*, *limonite*, *magnetic iron*, *flesh-coloured carb. lime*, *fibrous and rhombic carb. lime*, *magnesian carb. lime*.

ON THE IRON ORES OF THE GNEISSIC AND PALÆOZOIC FORMATIONS OF PENNSYLVANIA.

INTRODUCTORY REMARKS.

Few tracts of the earth's surface contain, in proportion to their area, so abundant a supply of the ores of iron as the State of Pennsylvania. There are particular localities in other regions where, perhaps, the quantity of iron ore is even larger than in any of the yet discovered deposits of this State, extensive as many of these are; but it is doubtful if any territory of its size possesses as enormous an aggregate amount of this form of mineral wealth in a position so accessible to the different kinds of fuel essential to its conversion to human use. The variety in the composition of these ores is not less remarkable than their amazing quantity; nearly every species employed for making iron being met with, and in some districts many kinds in a single neighbourhood. Their great diversity in chemical constitution and properties is of itself an advantage to the iron manufacture of the State not easily to be estimated. Taken in connection with a no less extraordinary variety in the fuel, embracing almost every known description of fossil coal and charcoal, it enables the iron-smelters of Pennsylvania, by the use of judicious mixtures, and the application of suitable fuel, to produce nearly every description of iron acceptable in commerce.

This very encouraging feature in the picture of the vast mineral wealth of the State is intimately connected with the enormous variety and wide distribution of the Palæozoic strata, and with the remarkable structure already elaborately explained, by which many different formations are brought together in the same districts in numerous narrow outcrops. It is primarily dependent on these two circumstances—first, that much ferruginous matter entered originally into the composition of several of our great Appalachian rocks; and secondly, that the subsequent changes of upheaval to the surface, and the chemical action upon these rocks, have brought the iron of each formation within reach in many successive parallel belts. If we regard the positions which the different iron ores occupy in the thick and diversified strata of this region, we perceive that, from the ancient metamorphic groups to the coal-rocks inclusive, almost every great series of deposits contains one or more special kinds of ore. In the gneissic or metamorphic series we meet with both the crystalline magnetic iron-ore and the brown peroxide. The Primal newer slate, and Auroral magnesian limestone, have each their own special varieties of the hæmatitic ores. The Levant series embraces a stratified fossiliferous ore of great extent and importance. There is a hæmatitic ore peculiar to the horizon of the Pre-meridian strata, and low in the Cadent series there occurs a form of ore unlike any belonging to the other formations. Near the base of the Ponent rocks we find a stratified and fossiliferous iron-ore essentially different in qualities and appearance from that of the Levant group; and in the Vespertine red shale a peculiar nodular ore occurs, occupying its own definite level in the formation, and visible along a very extended line of outcrop. Lastly, the various subdivisions of our vast coal-formation yield their own special sub-varieties, sharing certain common properties, yet differing both externally and in their chemical nature.

I propose to offer, in this division of my work, some general remarks upon the geological and chemical relations of the ores of each iron-bearing formation, with a few practical suggestions and calculations; and to accompany each such general sketch with a series of analyses sufficiently numerous to display the characteristic properties and relative richness in iron of particular varieties, and to append some condensed comparative statistics tending to show the present and future growth of the already vast and important iron-manufacture of Pennsylvania and other regions.

CHAPTER I.

OF THE IRON ORES OF THE METAMORPHIC OR GNEISSIC ROCKS.

Two principal varieties of iron ore occur in association with the gneiss rocks of the South-eastern district of the State. These are the crystalline-magnetic ores, and the brown or hæmatitic-peroxide ores. The chief localities of the first are in the N. belt, or that of the South Mountains between the Delaware and Schuylkill, while the greater number of those of the latter species are in the S. tract.

MAGNETIC IRON-ORE, OR OXIDULATED IRON.

This ore of iron, in its purest form, consists of two atomic proportions of the peroxide of iron and one of the protoxide, and therefore contains nearly 73 per cent of metallic iron. It is, however, seldom absolutely free from admixture of other crystalline minerals, the presence of some of which materially influence its value as a source of iron. It is strongly magnetic, attracting soft iron and the magnet, and many masses of it are endowed with true magnetic polarity, or are themselves native magnets. The minerals most generally interspersed among the crystalline oxides of iron are hornblende, felspar, quartz, sahlite, and apatite. Another ore of iron is not unfrequently associated with it—this is the *chromiferous iron-ore*, a combination of oxide of chromine with peroxide of iron and alumina. In the Serpentine belts of Chester and the Southern part of Lancaster counties, the chromiferous iron-ore is somewhat abundant, and, as I have stated, is mined in several localities, being chiefly transported to Baltimore, where it is applied to the manufacture of chrome-paints. The magnetic iron-ore occurs only in the form of true veins of injection or genuine mineral lodes. Its veins very generally coincide approximately in direction and inclination with the crystalline strata, between the layers of which they lie; yet this conformity is only partial, for when they are traced with close attention, they are occasionally found to intersect the strata for a short distance, and then resume their parallelism. These iron ores evidently reached the positions in which we thus find them while in a melted state, their intrusion being the result of an enormous subterraneous force, rupturing the earth's crust in the direction of the strata, or in the planes of weakest cohesion, and pressing the liquid ore and other fused mineral matters into the open fissures. Where the rent has been at all irregular or splintery, the vein which filled it is interrupted or uneven, being in some places pinched to very narrow dimensions by the approximation of its walls, in others dilating by their recession, and in many cases being split into two or more parallel branches by the insertion of a wedge-shaped portion of one or other wall. The veins incline at all angles between 45° and the perpendicular.

As a general rule, the lodes of magnetic iron-ore of the chain of the Highlands, tracing them from the Schuylkill to the Delaware, and then across New Jersey and New York, give evidence, in the nature and mode of distribution of the included crystalline minerals, of their having in many cases derived at least a portion of these from the fusion of the materials of the walls of the fissure into which the intensely-heated ore has flowed. It is indeed a very common fact that the foreign minerals in the ore are precisely such as would be produced by the melting and re-crystallising of the rocky matter in contact with the vein. I may mention, as worthy of record in this place, a general fact of some scientific and much practical value, in relation to the relative position of the oxide of iron and the non-metallic minerals in the same vein. Where the vein or dyke is large, and contains much extraneous mineral matter, this latter, if the inclination is not very steep or perpendicular, forms a separate division in the vein, and almost invariably *rests upon the ore;* but where, on the other hand, the dip is nearly vertical, the earthy minerals and the ore are more intimately mingled, or the respective masses of each intersect, or enclose each other irregularly.

The origin of these different conditions of insulation of the materials is very obvious. The oxide of iron, while the whole mass of the vein was yet in a state of fusion and very fluid, would necessarily, from its greater relative weight, follow the lower wall of the fissure as it flowed to the surface, while the much lighter earthy minerals would float, as it were, upon the upper side of the ore, taking the position with respect to the latter of its scoria or cinder. This would arise wherever the slope of the fissure was sufficient to give the force of gravity much control in the distribution of the materials; but in all cases of a perpendicular vein there would be no tendency in the heavier metallic portion to collect on one side rather than on another, and therefore it and the lighter mass would mingle more promiscuously. I first detected these phenomena among the magnetic veins of Orange County, New York, where the ore is often accompanied by much white felspathic granite, the product apparently of the fusion of the felspathic gneiss of its walls; and I have become confirmed in my impression of their generality by an extensive study of the veins of iron ore of the entire chain of the Highlands, from the E. side of New York to the River Schuylkill, and of many of the great magnetic dykes of the W. side of Lake Champlain.

There are many veins which are not accompanied by any separate body of granitic matter, but contain the felspar, hornblende, or other minerals in much abundance, disseminated through the ore. These we may imagine to have acquired their solid state, at least in the portions near the surface, where alone we can observe them, from a condition of imperfect fluidity, like that of the already half-chilled lava of some volcanic eruptions which would effectually prevent the separation of the heavier from the lighter constituents. Such are some of the gneissoid iron veins of the South Mountains E. of the Schuylkill. The Long Mine on the Sterling estate, 4 miles E. of the Ramapo, in New York, is a good example of the characteristic features of these lodes of magnetic oxide of iron: it displays the outcrop of two veins, each reposing directly upon gneiss, and covered by a thick vein, or rather division of the same vein, consisting of coarse white felspathic granite.

The mode of mining those veins, where the dip is not excessively steep, is to leave numerous staunch pillars of the ore, and to remove by blasting that which intervenes. A partially columnar structure, or cleavage, is sometimes visible as in the principal vein of the Sterling Long Mine, dividing the ore perpendicularly, or nearly so, to the surfaces which confine it. It greatly facilitates the operations of the miner. This structure, so analogous to that of many basaltic and other igneous dykes, is by no means infrequent in the large veins of magnetic iron-ore, and indicates a slow and gradual crystallisation from a state of fluidity.

Of the practical utility of the general fact which I have now announced respecting the frequent presence of some form of granite or unstratified rock, and the almost invariably overlying position which it occupies, one or two simple illustrations may be interesting. The first intimation usually procured of proximity to a vein of magnetic iron-ore is by the local disturbance it produces in the magnetic compass; but as the indications of the position of the vein derived from this instrument are frequently very vague and perplexing, it is of the greatest value to have some independent geological clue to its situation. Such, approximately at least, may be found in the usually conspicuous granitic outcrop of the upper half of the vein. When this is accompanied by a strong disturbing action upon the magnetic needle, we may infer, with a high degree of probability, that a metalliferous vein, large or small, lies immediately in contact with and below the dyke, and it is then only necessary to ascertain, from an inspection of the dip and direction of the adjoining gneiss, the lower edge of the granitic dyke, to have all the data requisite for finding the outcrop of the ore with very considerable certainty.

But this knowledge of the inferior position of the ore to the unstratified rock accompanying it, I have found useful in another way. It can be applied to tracing or recovering a vein of the ore thus overlaid by a mass of granite which has suddenly eluded the miner through the effect of some transverse fault or dislocation. Where the displacement, as usual, is to the extent of only a few yards, it is very obvious that, if the fault be an *upthrow*, the gneiss upon which the ore-vein rests will constitute the wall; whereas, if it be a *downthrow*, the granitic roof will lie athwart the original course of the vein.

The following is a sufficiently minute description of the magnetic igneous veins and iron mines of this formation :—

METALLIFEROUS VEINS OF THE SOUTH MOUNTAINS.

IRON ORES OF THE GNEISS.

The gneissic belt contains in several places veins of magnetic oxide of iron. These occur as regular lodes or veins, penetrating the gneiss and other rocks almost invariably in a direction coincident with the bearing of the strata. They might be taken, therefore, for interpolated beds, but for the occurrence of occasional branches and other irregularities which establish their intrusive origin. They agree in all their features with the larger and more numerous veins in the Highlands of New Jersey and New York.

IRON MINES OF THE LEHIGH HILL.

Beginning with the part of the belt next the Delaware, the first vein we encounter is upon the Lehigh hill, about 2¼ miles S. of Easton, a few rods N.W. of the old Philadelphia Road. The rock here is a mixture of quartz and felspar, with occasionally a little epidote. On the S. side of the ridge the strata are talcose. The vein of magnetic iron-ore lies in contact with a sienitic dyke, consisting largely of green sahlite. This vein was formerly mined, but the work has been long since abandoned. The ore, which is very compact, appears to have a N.W. dip.

DURHAM IRON-MINE.

Another somewhat noted locality is that of the old Durham iron-mine, which is on the top of the hill S. of Durham Creek, on the old Philadelphia Road. This mine has been neglected for many years.

Near Durham iron-works, and not far from the creek, there is a valuable vein of magnetic iron-ore, discovered a few years since, and now wrought for the furnaces. This lode varies in thickness from 2 to 14 feet, averaging about 6 feet. Its total length has not been ascertained, but up to the summer of 1856 a gangway had been driven along it for 850 feet. It ranges N.E. and S.W., and dips 45°. The ore is pronounced rich and excellent. Within a few hundred feet of this lode there is a deposit of rich hæmatitic ore, thought to be derived from it.

On the Northernmost of the two gneiss hills E. of the Saucon, and about a mile N.E. of Hellertown, a vein of magnetic iron-ore shows itself in several places, though the quantity of ore here is probably not great. It is much mixed with quartz, though we obtained some tolerably pure specimens. A sienitic dyke, composed chiefly of sahlite and hornblende, accompanies the ore, and seems to have been the chief object of attention to those who have undertaken mining here.

Fragments of magnetic iron-ore occur in many places on the surface of the bold hill of crystalline rocks S. of the Lehigh, at Bethlehem, where some search has been made for it by digging. South-west of Shimersville, near the E. end of the same ridge, a vein of green sahlite, which has been mistaken for iron ore, shows itself near the summit of a hill. Close to this spot, some true iron-ore was found by us, the source of which is probably a little N. of the sahlite. Epidote, mixed with iron ore, also occurs here. Farther W., near the summit of the same ridge, magnetic iron-ore in a talcose rock is visible, near Shuber's, 3 miles from Bethlehem; it has not been dug for. The same variety of ore, of excellent quality, is found on the surface, near the top of the N. gneissic ridge S. of Allentown, at a spot a little W. of the Philadelphia Road. A less magnetic variety is met with on the N. slope of the hill, a mile to the E. of the road. Farther to the S.W., the magnetic iron-ore shows itself in the hill 3 miles S.E. from Metztown, the spot being a little W. of the Philadelphia Road. It is on the S. side of the second gneiss ridge from the N. The ore occurs in three regular veins, dipping with the adjoining strata at an angle of 50° to the S.S.E. The S. vein is about 1½ feet thick; N. of it occurs a stratum of rock (gneiss), 8 feet across, in contact with which is the middle vein, separated near its outcrop into two branches, which at a little depth unite into one vein; this is bounded on the N. by a stratum of rock about 4 feet in thickness, and directly in contact with this is the third or N. vein, having a thickness of 2 feet. The rock which encloses these several veins is a coarse regularly-stratified gneiss, a mixture chiefly of quartz and felspar.

MOUNT PLEASANT IRON-MINES.

Some miles to the S. of the above locality, magnetic iron-ore occurs on the border of Colebrookdale and Hereford townships, in the Mount Pleasant iron-mines. In the N.E. excavation the ore occurs between sienitic rocks, and is itself a mixture of rotten sienite and magnetic oxide. It is worked open to the air in a drift 10 or 12 feet wide, ranging E. of N. The dip here is 65°, and a little S. of E. The quality of the ore is variable. A few hundred yards more to the S.W. is another mine; it includes two large excavations, pursuing apparently a regular vein or bed parallel with the strata. Two other excavations occur about 200 yards W. of S. from these. Here the bed has a nearly E. and W. direction, and may probably be the same which contains the mines just previously spoken of. This ore, more compact than that of the other mines, is stated to have made a rather red-short iron.

The next locality of importance is the old iron-mine belonging to Oley Furnace, nearly 2 miles N.W. from Friedensburg. At this spot the ore was dug from immediately under an outcrop of the Primal sandstone, the digging running parallel with it for more than 100 yards, and being 18 or 20 feet deep, and 8 or 10 feet wide. This mine, now abandoned, furnished us some specimens from the side-wall of the excavation; these are argillaceous and laminated, and of a purplish-red colour. A shaft unites the main excavation with another nearly under the first, having about the same direction, but descending more perpendicularly. This latter mine is from 3 to 5 feet wide; the wall is of metamorphic rock, chiefly felspathic and hornblendic gneiss, but sometimes entirely micaceous, and it contains, in certain places, magnetic and micaceous iron-ore. The rocks passed through in a tunnel are gneiss, sienite, hornblende, and micaceous slates.

On Pine Creek, in Pike Township, some diggings have been made for ore, about half a mile S.E. from Lobach's mill. The ore has the aspect of a talcose slate, charged with the oxide of iron; it has a laminated or rather a fibrous structure. There are several extensive mines at Boyerstown wrought chiefly by Reeves, Buck, and Company. The ore vein varies in thickness from a few inches to 20 feet. It resembles that of the Roudenbush and other mines near Reading. It dips S., and ranges E. and W. It has been wrought by shaft and slope.

Near Pricetown, on Rauzbaun's farm, an old pit or shallow shaft has been reopened. The ore is highly magnetic, and of an excellent quality, but the vein is not a promising one, being only a few inches thick.

At Roads's, nearly 2 miles E. of Pricetown, there is a vein of superior magnetic iron-ore, said to be between 5 and 6 feet thick. Its dip is perpendicular.

In Alsace Township, a vein of the ore has been opened $2\frac{1}{2}$ miles S. of the canal. This vein occurs in gneiss rock, and is double, being divided by a wedge of granite, or granitoid gneiss. The strata dip S. 80°, and the vein has the same inclination. The whole thickness of the vein is about 8 feet, but the good ore measures only 4 feet, and this is in two veins of 2 feet each, the rest of the ore being very inferior.

PENN'S MOUNT ORE-VEIN.

In the district we are now describing, though not strictly within the gneiss itself, there is an important vein of igneous iron-ore, which has been wrought for some years. It is opened on Penn's Mount, about half a mile E. of Reading.

The vein apparently is injected conformably to the bedding of the Primal white sandstone, and the ore is not accompanied by any bounding wall of igneous rock, but is in immediate contact with the sandstone itself. The latter rock disintegrates quickly on exposure to the atmosphere, and develops innumerable small grains of hornblende, which speckle the yellowish-grey sand. The ore-vein ranges from the Reading Fair ground, a little S. of E., dipping 45° S. Its thickness is seldom less than 18 inches, and has been as great as 28 feet. Under this enlargement it does not appear to suffer in quality. The ore itself is of the granitoid variety, highly crystalline, containing quartz and felspar, especially the latter, in great abundance: hornblende and apatite enter also into its composition.

The vein has been wrought at its surface, outcropping in the Reading Fair ground, and for one-third of a mile E., by Eckert and Brother, the Phœnixville Iron Company, and others, on the lands of Mr Oakley and B. Davis. The principal mine is the vertical shaft of Eckert and Brother: this is sunk 142 feet to the level of a tunnel, which is cut N. 28 feet through rotten sandstone to the top of the vein. From this tunnel the vein is followed by a gangway 30 feet E. and 115 feet W. The ore is worked along the foot-wall rising towards the surface, the hanging wall or roof being supported by timbers. The length of breast to the old surface-level workings is 72 feet. The ore from this old level was obtained to a depth of 82 feet. The Phœnixville Company are now obtaining their ore from a surface-level and whim-shaft E. of Eckert's Mine. In Eckert's old level, 100 feet W. of the whim-shaft, the vein split, but the north branch vein thinned away in 100 feet.

The *Island Mine*, situated on an island in the Schuylkill, one mile below Reading, has been wrought by Eckert, Syfert, and Company, but is now, perhaps temporarily, abandoned. The vein dips about 40° N.W. It is overlaid by dense brecciated limestone, locally known as "all sorts" limestone. This is, no doubt, the Mesozoic conglomerate, which appears in the opposite bank of the river *in situ*. The N.W. dip of this rock has no doubt regulated the dip of the injected material. The under-rock of the vein we do not certainly know, but from the specimens seen, it appears to be an impure silicious limestone, or that usually termed "bastard." The surface of the island is strewn with igneous rocks, but we are informed that none are found in contact with the vein.

The iron-ore vein, which is in thickness from a few inches to 15 feet, is a heavy, fine-grained slate-blue rock, containing lime in its constitution, and decomposing rapidly on exposure to the atmosphere. When decomposing, it assumes a deep sea-green colour, and develops copperas on the surface, from the sulphuret of iron in the ore. In some specimens the pyrites have so much the aspect of sulphuret of copper that chemical evidence is required to correct the impression.

A slope has been sunk upon the vein 90 feet below the surface, and, 28 feet above its foot, gangways are driven along the vein 20 feet towards the N.E., and 250 feet S.W.

About half a mile W. of the preceding is the *Roudenbush Mine*, which, we are informed, yields its proprietors at the Phœnixville furnaces 5000 tons of ore per annum.

The vein ranges a little N. of E. Its foot-wall is white metamorphic limestone, or marble, and its hanging-wall, or roof, a dull sea-green serpentine-like rock, which on exposure soon crumbles down like ordinary shale.

The vein, dipping 36° S., is followed by a slope 280 feet beneath the surface. At the bottom, gangways are driven 200 feet W., and 400 feet E., to a fault cutting out the vein. A higher level, 160 feet from the surface, is driven 300 feet E. The ore is now taken from this level.

Like all others, this vein is exceedingly variable; while wholly or almost entirely absent in some places, in others it has been found 30 feet thick. Its average bulk will not exceed 12 feet.

The gangue-stone of the ore is a light-blue rotten limestone, from which the ore is scarcely distinguishable, except by its greater weight and deeper tint. Of the entire ground wrought, about one-half the material is sufficiently rich in iron for the furnace; the remaining rubbish is used as stopping in the old workings.

The *Wheatfield* Mining Company have opened a series of veins about 5 miles W. of that last described. At this locality there are already proved about ten veins of igneous ore, ranging N. and S., and all included within a transverse distance of 150 feet. The maximum thickness attained by any one of these veins is 8 feet. They are opened from the surface over an irregular area to a depth of about 40 feet, and have been followed along the outcrop from 50 to 110 feet. They occupy loose unstratified ground, including igneous rocks, to the depth at which they have been mined; and below that, as they are included in the beds of the Mesozoic conglomerate, they become pyritous, and are not wrought.

The ore is similar in general aspect to that of the two last-described mines. It frequently encloses fine crystals of calc-spar.

A narrow valley separates these veins as far as they have been traced N. from an E. and W. vein, which is worked by a slope. This vein dips 30° S. It is underlaid by a foot-wall of trap, and overlaid by white crystalline marble. The thickness ranges between 2 and 12 feet. There is a strong admixture of lime in the ore. The slope is sunk 78 feet, and a gangway is driven 110 feet E.

In the range of the E. and W. vein of the Wheatfield Company, but a fourth of a mile farther W., is situated the *Henry Ruth Mine.* The vein, which is, in all probability, the same, having similar walls both above and below, dips 25° S., and has exceeded 15 feet in thickness. The slope upon it is 120 feet long, and gangways are driven 45 feet W. and 60 feet E. It has been also wrought at the surface outcrop.

An analysis of some of the ores of the gneiss, including a few of those of the South Mountain range, is here appended.

ANALYSIS OF IRON ORES OF THE GNEISSIC ROCKS OF PENNSYLVANIA.

Localities.	Peroxide of Iron.	Protoxide of Iron.	Silica.	Alumina.	Magnesia.	Lime.	Potash.	Titanic and other acids.	Water.	Metallic Iron in 100 parts.	Description of the Ores.
Near Isabella Furnace, Chester County, . . .	...	76.86	...	...	...	...	...	Tit. acid, 2.39	...	59.44	Black, lustre metallic, foliated and granular, magnetic polarity.
Yellow Springs, Chester Co.,	82.91	...	3.32	1.35	...	...	...	...	13.90	57.55	Brown hæmatitic ore, lustre resinous.
Fegle's Mine, 3 miles S.E. of Metztown, Berks County, .	88.92	...	10.60	a trace	...	...	...	...	0.20	65.52	Iron-black, imperfect crystalline, splendent, magnetic polarity.
1 mile S.E. of Millerstown, Lehigh County, . .	85.50	...	12.60	a trace	...	...	...	...	1.25	63.00	Iron-black, lustre semi-metallic, imperfect rhombic crystals, magnetic polarity.
Schmultz Farm, Alsace, Berks County, . . .	57.10	24.50	12.10	4.15	0.52	0.60	..	Tit. acid, 0.75	0.28	58.95	Iron-black. imperfect crystalline, magnetic, specks of hornblende, from the richer part of the vein.
½ mile E. of Reading, Penn's Mount, ...	36.50	16.25	24.17	6.20	7.10	5.67	3.30	Phos. and fluor. acids, 0.81	...	37.00	Crystalline magnetic ore, with hornblende, felspar, quartz, apatite.

CHAPTER II.

IRON ORES OF THE PRIMAL SERIES.

The slates of the Primal series, especially the upper Primal slate, yield two classes of iron ore: one, a very ferruginous variety of the rock itself, under conditions of more or less metamorphism; the other, a class of rich brown hæmatitic iron-ore of superficial formation. To the first class belong the valuable and noted mines of Cornwall, in Lebanon County, the Jones Mine in Berks, and partially the Chestnut Hill Mine near Columbia, and some of the ore diggings near Safe Harbour. At all of these localities the ore appears to be an original constituent of the Primal slate, but to have undergone a more or less degree of segregation from the substance of the rock by some agency connected with the metamorphism of the stratum. In many parts of the mass the oxide of iron is in a crystalline condition, dispersed in small specks throughout the other mineral constituents of the rock, which retains all its original features of stratification, and which resembles very much a mica-slate, or other metamorphic schist. This highly-altered ferruginous form of the rock is also in many instances subdivided by innumerable cleavage-fissures, the effect of which has been to change the semi-crystalline magnetic iron-ore to the ordinary brown peroxide or limonite by the copious admission of the surface waters and atmosphere into the body of the rock. In some spots, long exposed to abundant soakage through the cleavage-cracks, the iron ore is not only thus changed, but is actually collected into the deep narrow clefts of the rock worn by the percolation of the waters in the direction of the cleavage, so that in a cross section of the mine we may witness the curious anomaly of the ribbon structure or laminæ of stratification dipping one way, and the plates or veins of the accumulated iron-ore, and its associated clay, dipping independently at a steep intersecting angle.

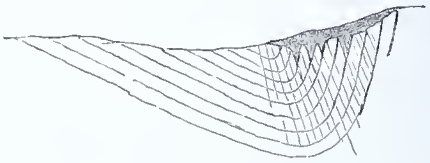


FIG. 573.

The annexed little cut (Fig. 573) exhibits a synclinal basin of the Primal slate thus percolated with ore to a certain distance from the surface in the direction of the cleavage-fissures.

An illustration of this mode of accumulation of the iron ore in the clefts connected with cleavage has been already furnished in Volume I., page 218, where a section is shown of the Rathfon Ore-bank, near Safe Harbour (see fig. 27), the only difference being, that the rock is the Auroral magnesian limestone, interstratified with talcoid slate, and not the Primal slate itself.

The other kind of ore derived from the Primal slates is the hydrated brown peroxide deposited upon the surface of the formation from the ferruginous loamy matter derived from the complete disintegration of the slaty rock. Nearly all the large deposits of the formation contain a greater or less proportion of this species of ore, and some of them consist of it almost exclusively. In the extensive open cutting called the Chestnut Hill Ore-bank, near Columbia, of which a description has already been given (Vol. I., p. 182), much ore is seen to pervade the lower layers of the altered Primal slate, while a large and dense body of the peroxide of iron has been accumulated at the very base of the formation, by a downward soaking of the surface-water collecting and concreting the ore in a dense and thick stratum or rude mass upon an impervious floor of close-grained Primal white sandstone.

The following circumstantial description of the iron mines at Cornwall, Lebanon County, shows the several phases under which both classes of the Primal ores, the segregated semi-crystalline and the concreted hæmatitic varieties, prevail.

At this locality the actions collecting the oxide of iron into its present conditions have been somewhat complicated. The ferruginous Primal slate has been metamorphosed, and its oxide of iron segregated and crystallised through the influence probably of highly-heated volcanic steam, and the same influence has produced a very general cleavage-structure. During the same action, or subsequently, numerous injections of molten hot lava, resulting in dykes of trap-rock, have invaded the stratum, and have still further changed the condition of the mass, infusing among it, probably by sublimation, some trappean mineral matter, and especially some sulphuret and carbonate of copper; and since these subterranean influences, the atmosphere, through its rains, has exerted itself through countless ages to modify still further the chemical and physical conditions of the shattered and fissured mass, and its contained oxide of iron.

CORNWALL IRON-MINES.

This great iron-ore deposit, by far the most extensive, and one of the most interesting in the State, is situated at the outcrop of the Primal upper slates, where they rise from beneath the Auroral limestone in

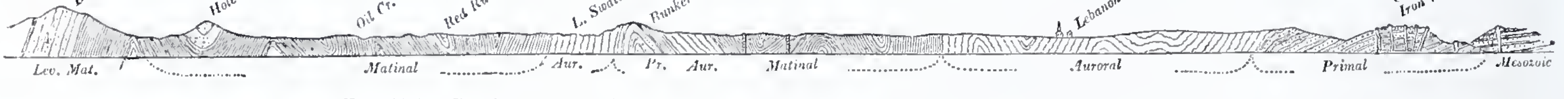


FIG. 574.—Section across Kittatinny Valley, from Blue Mountain to Cornwall, 15 miles.

Lebanon County, on the S.E. border of the Kittatinny Valley. The geological relations of these mines on the border of the Kittatinny Valley are shown in Fig. 574.

The ore strata are embraced in three hills, having a nearly E. and W. range. These hills are flanked to the N. by the Auroral limestone, and S. by the overlapping unconformable Mesozoic red sandstone, which forms a high ridge prolonged E. and W., and overlooking the valley. Their position is five miles S. of the town of Lebanon.

The Eastern or "Big" Hill is elevated 312 feet above the level of the creek at its base. The middle hill is 98 feet high, and the western hill 78 feet high. The peculiar features of each of these will be considered in detail.

The bounding wall of the ore in the Big Hill is a heavy dyke of trap, which varies in regard to texture and composition as the felspar or hornblendic element predominates. This massive dyke, the thickness of which seems nowhere less than 40 feet, and probably greatly exceeds this, encircles the hill on three sides, the S., E., and N., somewhat in the form of a horse-shoe. The N. limb rises from the water-level at an angle of 60° or 70°; on descending to the water-level upon its S. limb, the dyke bends sharply S., and is obscured by surface debris. Besides this general outer wall of trap, there are several smaller dykes of the same material; some of these appear to be offshoots from the main dyke, and are found in one or two instances interstratified with the ore. In other cases they appear as simple isolated columns of rock, surrounded by ore, and not traceable longitudinally through the hill, as the section would imply. At water-level, on the W. side of the hill, the two limbs of the ore enclosing trap are about 400 feet asunder, but on the hill-top, as a consequence of their opposing dips, they are 500 feet, or even 600 feet apart.

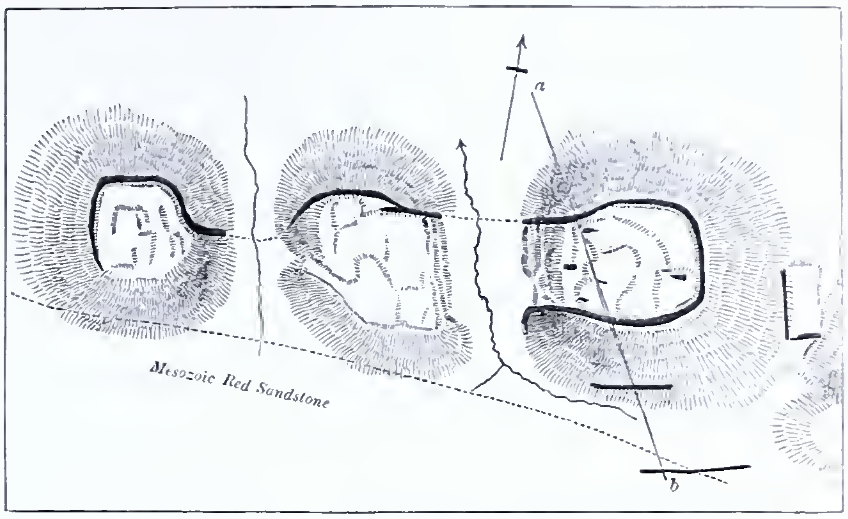
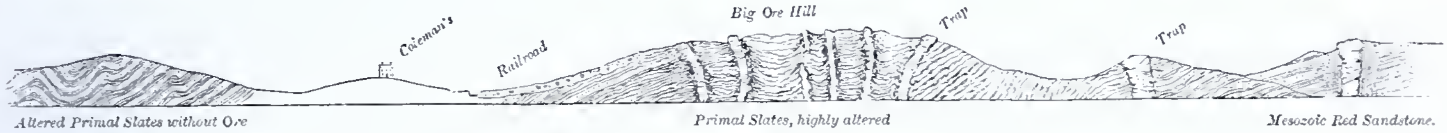
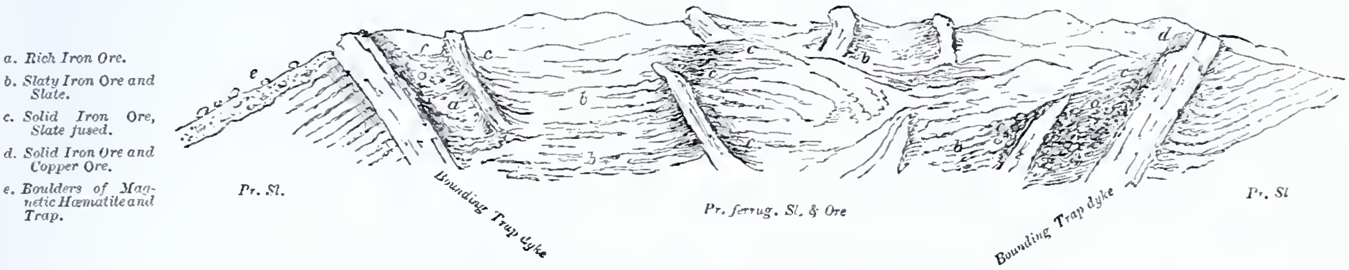


FIG. 575.—Map of the Cornwall Ore Hills, Lebanon County.


Coleman's
Railroad
Big Ore Hill
Trap
Trap
Altered Primal Slates without Ore
Primal Slates, highly altered
Mesozoic Red Sandstone.
FIG. 576.—Section through Cornwall Iron Mines, Lebanon County, along line *a b*.

The ore in this hill is nearly horizontally, though irregularly stratified, and presents every possible aspect, from slaty greenish-grey to dark green and dark ferruginous brown and black: the latter variety is found chiefly in the vicinity of the trap dykes, and large masses are strewn extensively upon the hill-sides, especially upon the N. and S. slopes. This variety, known locally as the Nigger-head ore, is very highly endowed with magnetic polarity. As we recede from the vicinity of the intrusive rock, the ore becomes lighter in hue, and more slaty in texture. In parts of the mine these slaty portions are too poor in iron to be wrought. With the exception of those portions of the ore which are closely adjacent to the trap, the mass teems with crystals of sulphuret of iron; almost every hand-specimen displays many specks and small intersecting veins of it. This pyrites increases in abundance as the mining penetrates beneath the surface, or as the ore has been unaffected by atmospheric influences.


a. Rich Iron Ore.
b. Slaty Iron Ore and Slate.
c. Solid Iron Ore, Slate fused.
d. Solid Iron Ore and Copper Ore.
e. Boulders of Magnetic Hæmatite and Trap.
a
b
c
d
e
Pr. Sl.
Bounding Trap dyke
Pr. ferrug. Sl. & Ore
Bounding Trap dyke
Pr. Sl
FIG. 577.—Big Mine Ore Hill, Cornwall Iron Mines, Lebanon County.

Copper ore is found at times, in the form of green carbonate and grey oxide, impregnating the iron ore, but it does not appear as a vein, nor is it in contact with the dykes of trap, though probably introduced at the time of their intrusion.

The iron ore hitherto obtained from the Big Hill has been taken from shallow excavations at the surface; it is now wrought exclusively at the W. base, where successive benches are cut down from the surface to the railway level.

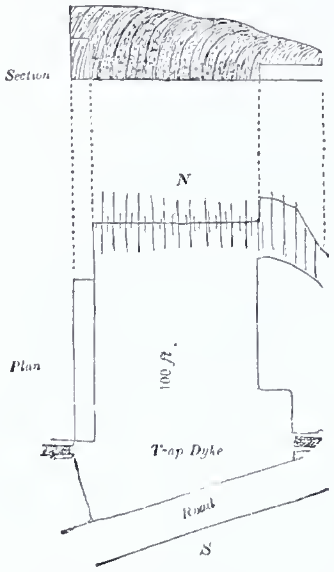


Fig. 578.—Ore Quarry, E. base of Big Hill, Cornwall, Lebanon County.

At the E. base of the Big Hill there is a small rectangular excavation (see Fig. 578) of black and yellow crumbly ore, the bedding of which is nearly vertical, ranging N. and S. parallel to the face of a trap dyke which bounds it. This wall of trap is parallel to that at the E. edge of the Big Hill, 200 yards distant: whether it is the outer face of the same great dyke has not been determined. On the E. side of the pit another dyke of trap is visible, but the excavation has not been sufficiently extensive to determine its range or amount. A third narrow dyke crosses the S. end of the excavation. The ore at this mine is granular and black, chiefly crystalline, or dark grey, in the vicinity of the trap; and in other places it is yellow and dark green, from atmospheric action.

The Middle Hill, separated from the Big Hill by a narrow valley, through which flows a small stream known as Saddler's Run, is that from which at present the ore of the district is chiefly obtained.

The N. wall of the ore is the prolongation W. of the trap dyke which forms its N. boundary in the Big Hill. This dyke ranges W. through the Middle Hill, deflecting gently S. along its W. slope; it then crosses the valley, separating this from the W. ore hill, and soon after turns N., then W., and finally curves S. round the end of the latter, and is lost to view. Owing to the S. turn of the Southern limbs of the dyke at the W. base of the Big Hill, it does not cross the valley, and does not appear in either of the two W. hills, in both of which the boundary of the ore at the surface is formed by the overlapping debris of red sandstone and conglomerate from the neighbouring hills. The general appearance and character of the ore in the Middle and Western hills is similar to that of the Big Hill. It is slaty throughout, and very pyritous; for which reason it soon crumbles under exposure. In those parts of the mine where the ore has been cut down cheese-like by the miners, the natural bedding of the mass is curiously contorted and irregular along a general horizontal plane. On the S. side of the Middle Hill, the excavation has reached the water-level. In the pit, large masses of light blue flinty and magnesian limestone are found imbedded with and surrounded by ore. They are devoid of regular form. In like manner, masses of quartz are found as bunches in the bedding of the more slaty ore. In some of these, thin scales of native arborescent copper occur, though not abundantly. The white cupreous quartz seems to be derived from a vein of that material. The limestone is evidently not *in situ*.

On the Middle Hill several small veins or bunches of copper have been wrought to a limited extent. Four of these range N. and S., with one exception dipping W. The direction of the strike is at right angles to that of the iron ore, which dips N. about 30° in this part of the mine. The thickness of these veins varies between half an inch and 3 inches. A fifth vein may be traced on an E. and W. range at the S. limit of the mine. This lode is occasionally entirely absent, but is in some places a foot in thickness, dip S. 45° to 50°. It should be remarked that these lodes of copper are thick where the iron ore is soft, and that they thin away when the bounding walls of the iron ore are hard and pyritous. The usual varieties of copper ore extracted are grey protoxide, bright red dinoxide, green and blue carbonates of copper, intermixed with sesquioxide of iron and iron pyrites; also rich specimens of the sulphuret associated with green and blue carbonates of copper. The lodes are nearly all accompanied by veins of green steatite. They have not been traced across the ore-deposit to the bounding trap-rock, but have been found within 50 yards of it, growing perceptibly thinner. When followed below the surface, they become poor in good ore, and merge into copper and iron pyrites. The annual yield in copper ore does not exceed 100 tons. It is smelted in Baltimore, and yields, we are informed, from 15 to 23 per cent of copper. The average annual product of iron ore is about 120,000 tons, but the mine is susceptible of being wrought upon almost any scale. A small ore-pit, from which no ore is at present extracted, known as the Doner Mine, is situated 1½ miles E. of Cornwall. The ore, though of the magnetic variety, appears in irregular bunches and nests. No trap injections are found in the vicinity. The deposit is quite near the limestone, and is intermixed with sand and gravel.

Those interested in the discovery of iron ore in this part of Pennsylvania should explore carefully the more metamorphosed tracts of the Primal slates, especially where these adjoin the limestone.

SURFACE IRON-ORES OF THE PRIMAL SERIES.

The Primal newer slate sustains extensive surface-deposits, of a somewhat distinctive variety, of brown hæmatitic ores, a few descriptive and theoretical observations upon which may not be out of place here. These relate not only to the ore of this formation as it is seen in Pennsylvania, but to the whole enormous outcrop of the stratum wherever it is largely developed from E. Tennessee to the Green Mountains of Vermont.

This iron ore is lodged in extensive accumulations of yellow ferruginous loam and clay, occupying hollows or basins in the surface of the Primal newer slate, at the N.W. base, or low on the N.W. slopes, of the ridges and spurs of the S. Mountains of Pennsylvania, or of their prolongation the Blue Ridge in Virginia and Tennessee, and the Green Mountains in Vermont. Diluvial waters have apparently caused these deposits of loam, into the lower parts of which the particles of the oxide of iron have been conveyed by the dissolving and transporting action of percolating waters, and there collected into irregular nodular masses of very various structure. Some of these are stalactitic, but the ore of the Primal slate is more frequently in roundish cellular lumps, and even sometimes in hollow bomb-shaped geodes. The latter often consist of crystallised fibrous hæmatite, but the earthy brown hydrated peroxide is by far the most commonly met with. The masses are distributed in the loam without definite stratification, or any apparent order, being in greatest abundance towards the bottom of the deposit.

In some of the present class of mines, though not in all, there occur, mingled with the iron ore, small masses of peroxide of manganese, and these are occasionally stalactitic in their form. The oxide of manganese is, moreover, chemically combined with the oxide of iron in much of the iron ore, and, when in any considerable abundance, is a serious hindrance to the fusion of the ore in the blast-furnace. For this reason it is that these ores have usually been less in favour with our iron-smelters than the purer varieties which overlie the adjacent tracts of the Matinal limestone. Respecting the ultimate source of the oxides of iron and manganese, it is to be sought in the ferruginous slates upon which the deposits repose. The loamy soil imbedding the ore appears to have been derived from the disintegration of the slate previously collected in a fragmentary or even pulverised condition in the depressions of the surface. Under the action of the percolating rain and springs, these materials would be converted into a mere loam, and the oxide of iron set free. Much of the iron has been originally in the condition of the sulphuret of iron, diffused in minute crystals through certain layers of the slate. The facility with which this mineral undergoes decomposition, and gives rise to hydrated peroxide of iron upon the access of atmospheric air and the rain water, is a fact familiar to chemists. This view of the origin of a part at least of the ore, accords with what is known concerning those slaty rocks which contain much sulphuret of iron.

Such strata become changed in their exposed or outcrop portions with the brown peroxide, and, where circumstances have favoured a deep and general decomposition, we find nests and seams of the peroxide associated with masses of the rock in all the intervening stages of chemical change. Among those older metamorphic micaceous and talcose schists which are sufficiently pyritous, these conditions are as frequent as among the slates, shales, and limestones of the Appalachian Palæozoic formations. The separation of the peroxide of iron from the other materials of the disintegrated slate, is sometimes so complete as to leave a white earthy residuum of finely-subdivided particles, having the character of a pure silicious clay. This occupies the interstices between the nodules of ore, and is common in the interior of the hollow masses. So entire a separation of the oxide of iron from the earthy substances as this clay manifests, must be attributed to some further action than the mere transporting power of the percolating waters. It seems to imply the operation of a *segregating force* among the particles identical in chemical nature, in obedience to which the atoms of oxide of iron have detached themselves from the other matter, and concentrated themselves around particular centres, as in other cases of nodular concretion.

ANALYSES OF SPECIMENS OF HYDROUS PEROXIDE OF IRON OF THE PRIMAL SLATES, PENNSYLVANIA.

LOCALITY.	Peroxide of Iron.	Oxide of Manganese	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
Chestnut Hill, near Columbia, .	84.39	...	2.46	2.38	10.99	...	...	58.51	Brown, compact, mammillary, outer part crystalline and radiated.
Susan Ann Furnace, York County,	40.71	8.91	2.84	39.56	7.98	Phos. acid.	...	28.23	Blackish-brown, micaceous, and sandy.
Ege's Mountain Bank, S. of Carlisle Ironworks, Cumberland County,	49.80	17.55	0.10	20.10	12.0	...	.45	33.86	Dull purplish-brown, amorphous, brittle, earthy.
A mine ½ mile from Carlisle Ironworks, ...	27.93	a trace	a trace	3.30	2.81	Magnetic oxide 64.79	.17	65.88	Dull-black, sub-crystalline, slightly magnetic, resembles ores near trap-dykes.
Mountain Bank, Carlisle Ironworks,	70.04	3.32	a trace	16.32	10.96	...	...	48.56	Brown, mottled, rather cellular, "honeycomb ore."
Miller's Mountain Bank, Cumberland Furnace, Cumberland County, .	74.08	...	0.04	12.00	12.0	...	.8	52.36	Brown, hæmatitic, and porous.
Peffers' Bank, 6 miles S.W. of Carlisle, Cumberland County, . .	69.04	...	4.03	12.01	14.0	...	.2	48.58	Dark brown, with ochreous spots, compact.
Mine 1¾ miles from Carlisle Ironworks, ...	85.65	...	a trace	4.05	8.80	...	.90	59.95	Chestnut-brown, stalactitic, pipe small.
Pond Bank used at Caledonia Furnace, Franklin County, . .	79.05	...	a trace	9.30	12.00	...	...	55.33	Dark chestnut-brown, hæmatitic, imperfectly crystallised.
Hill Bank, Southampton Furnace, Franklin County, . . .	78.85	a trace	2.70	5.90	12.50	...	.05	55.19	Chestnut-brown, cellular; cells sometimes crystalline.
Hill Bank, inferior variety, . .	76.30	1.00	1.80	5.80	14.50	...	.60	53.41	Dark and light brown alternating, cellular and amorphous.
Montalto Furnace (lower ore), Franklin County, . . .	75.02	...	3.03	7.00	14.0	...	.5	52.64	Dark brown, cellular; cells lined with light ochreous matter.
Montalto Furnace (upper ore), .	71.00	...	2.05	13.03	12.6	...	.6	49.70	Mottled-brown and ochreous, parts compact, parts soft and cellular.
A mine 1 mile S.W. of Hughes' Forge, Franklin County, . .	79.10	4.00	1.40	2.80	12.0	...	.70	55.37	Dark brown, massive, compact, lustre resinous.
Pond Furnace Ore, Franklin County,	73.05	a trace	2.06	10.00	13.0	...	.9	51.35	Brownish-yellow, semi-crystalline, and mammillary, hæmatitic.

The peroxide of iron is very slightly, if at all, soluble in pure water, but is dissolved to a certain extent by water impregnated with *carbonic acid.* The superficial waters containing a portion of this acid, derived from the atmosphere, through which they have all fallen in the form of rain and snow, are capable of slowly conveying the peroxide in a state of solution from the surface to the deeper parts of the mass, where, by the gradual escape of the carbonic acid, the peroxide has become deposited. In the decomposition of the common sulphuret of iron, such as is found in pyritous slates, the sulphate of iron formed is *very soluble;* and this, pervading the surrounding mass, has gradually given up its oxide of iron by a decomposition promoted by the presence of earthy and especially of calcareous matter. The preceding analyses display the composition of the several varieties of the brown ores of this formation.

CHAPTER III.

IRON ORES OF THE AURORAL AND MATINAL SERIES.

Respecting the origin of the Auroral limestone ores, there appears to be no necessity for referring to any other agencies than those alluded to in treating of the history of the ores of the Primal series. Waters impregnated with salts of iron readily deposit the peroxide when in contact with carbonate of lime, and we might therefore look for deposits of the ore in situations favourable to the accumulation of the debris of ferruginous slates, and to the infiltration of waters charged with sulphate of iron derived from the decomposition of the sulphuret contained in such slates. Many of the layers of limestone, especially those of a slaty structure, contain much sulphuret of iron, and the great mass of the Matinal limestone formation includes a large amount of but slightly calcareous slates, more or less pyritous in their composition.

Among the circumstances which usually indicate an abundance of the limestone ore beneath the soil, it should be mentioned that one of the most essential is a considerable thickness in the deposit of ferruginous loam, clay, or other earthy matter, resting on the strata. This will, of course, be marked by a corresponding evenness of the surface; for where the beds of limestone are naked of soil in many places, the covering of earth, which must contain the ore, can nowhere be deep. Another very necessary condition is, that the earth overlying the rocks should have a large amount of the oxide of iron diffused in it. This will show itself by a characteristic bright yellow or clear brown colour. It must be observed, however, that the existence of a large quantity of oxide of iron in the deeper part of the soil will very frequently not be perceptible in the colour of the surface of the ground—the ore being confined to the lower portions of the mass—so that much good ore-ground is often neglected from want of perseverance in digging.

The iron ores of the Matinal slates are obviously traceable to sources similar to those of the ores of the Primal slates and Auroral limestone. In the Matinal slate ores, the proportion of oxide of manganese is often very great, and not unfrequently the ore passes in neighbouring beds into nearly a pure oxide of manganese. Indeed, it is chiefly in the upper part of the Matinal slates, and in the Primal slates, that this latter mineral is met with in deposits of sufficient extent to be valuable. The olive-coloured layers of argillaceous and sandy slate, forming a chief part of the Matinal newer slate, owe their colour in great part to the large amount of protoxide of manganese which they contain. In the disintegration of the rock this is dissolved, and, being converted into peroxide by exposure to the atmosphere, is deposited in irregular layers or concretions in situations favourable to its accumulation.

Having in Vol. I. page 263, expressed a hope of being able, before the completion of this work, to present some more recently-collected details of the Surface Iron Ores of the Kittatinny Valley, I here introduce the results of observations since made respecting the chief mines between the Delaware and Schuylkill rivers.

IRON ORES AND MINES OF THE KITTATINNY VALLEY.

I.—OF THE DISTRICT BETWEEN THE DELAWARE AND LEHIGH RIVERS.

Goetz Mine.—This is an old and extensive pit, and the only one from which ore is regularly obtained in the district N.E. of the Lehigh River. It is situated within the valley of limestone, 4 miles N. of Bethlehem. The excavation, which has reached a depth of nearly 60 feet, extends over two-thirds of an acre. The ore is chiefly a bright red hæmatite or hydrated sesquioxide of iron, the origin of which is clearly betrayed by numerous large masses of silicious rock found in the mine. These masses closely resemble the ore externally, and are, indeed, partially converted for some distance beneath the surface. In one part of the mine the rock was found somewhat regularly bedded over a mass of ore and clay, but it has been cut away to reach the materials beneath. In its texture it is a rather coarse sandstone of limestone-blue colour, and evidently contains lime. It may be termed a very sandy limestone, or calcareous sandstone.

The bed of ore at present mined underlies a thick mass of light-blue and ferruginous-brown clays. Its dip, which is flat near the surface, steepens to 45°, and again turns nearly horizontal at the floor of the mine. It crops out towards the N.W. In thickness the bed varies from a few feet up to 15 feet. In the S.E. parts of the mine no ore is at present excavated, and rubbish has obscured the bedding, if it has any. The clays contain disseminated masses, which may be separated from impurities by washing. The nearest rock-exposures are of limestone, dipping S.E. at a high angle. The yield of the mine does not exceed 4000 tons per annum.

II.—OF THE DISTRICT BETWEEN THE LEHIGH AND SCHUYLKILL RIVERS.

Beisel's Ore-Mine is situated on the Catasaqua and Foglesville Railroad, 5 miles from Catasaqua. It is an open pit of red hæmatitic ore, lying closely adjacent to a ridge of limestone which dips nearly vertically S.E. The ore is irregularly deposited, not in any stratified bed, but in nests or bunches, and cannot be traced to any considerable distance from the mine. The pit, which is 50 feet deep, is wrought for the Lehigh Valley Furnace, the ore being raised by an inclined plane and horse-power. A fourth of a mile S.E. of the mine rises a conspicuous ridge of calcareous slate, and at the foot of this is the

Trexell Ore-Mine, wrought by the Crane Iron Company. The ore is raised by steam-power, from a shaft sunk 60 to 70 feet. It is very irregularly disseminated through clay and earth, but little lump-ore being found. All the material raised from the pit requires washing, and the ore is not very abundant. The yield of the mine is 2000 tons per annum. In neither this nor the preceding mine has the rock-floor been reached.

Ritter's Bank is at the foot of the limestone ridge, in the prolongation of Beisel's ore-deposit, and but a few hundred yards distant. It is but recently opened, and the mine is small. In character and mode of deposit it in all respects resembles Beisel's. The ore is smelted at the Lehigh Valley Furnace.

The Guth Mine has been wrought for many years, and is now leased to the Crane Iron Company. It is situated on the W. side of the prolongation of the limestone ridge which passes Beisel's and Ritter's mines. This is apparently a monoclinal ridge of limestone dipping steeply S.E. The ore at the Guth Mine occupies a narrow trough which has been carved out of the limestone, as shown in the annexed cut. At its E. outcrop the ore was 20 to 30 feet thick, and inclined 75° W. It rests upon clay and sandy debris, and is overlaid by black clay, containing a large quantity of sulphuret of iron. This is capped by a tough white clay, which, when wet, assumes a semi-fluid condition, and soon covers the freshly-cut face of the mine. The insecure character of such a roof has prevented the mining of the ore where the increasing thickness of the covering makes it too expensive to remove it from the ore. Within 80 feet of the surface the ore-bed basins, but is somewhat thinner, and rises to the surface upon an E. dip, within 200 feet of its E. outcrop. On this side the ore has not been extensively wrought. The basin rises out within 100 feet N.E. from the pit, and the ore cannot be traced farther in that direction. In the main pit the ore is a velvety brown and black hæmatite, changing to red near the outcrop at the N.E. end of the mine. S.W. of this pit there are two others, within a few hundred feet. In the first of these a shaft, sunk to a depth of 80 feet, passed perpendicularly through 40 to 45 feet of dark-brown and black crumbly ore, dipping steeply N.W. Between this mass and that in the preceding pit the connection has not been traced, the thickness of the ore-deposit having greatly dwindled in the interval. The third opening does not merit attention; it was abandoned because of scarcity of ore. The yield of these mines is about 5000 tons per annum.

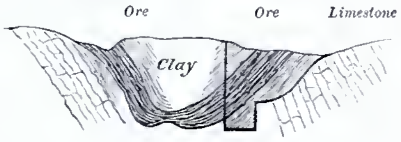


FIG. 579.—Guth Mine.

Kern & Albright's and *Hoffman's Mines*, closely adjacent to one another, are situated half a mile S.E. of Siegerville, and a fourth of a mile from Jordan Creek. The bedding of the ore in the former pit dips N.W. 20°, and rises upon the opposite dip in Hoffman's Mine. The two outcrops are about 500 feet asunder. In neither of these openings has the bottom of the ore been reached, though from 20 to 25 feet in thickness have been wrought. The ore is a brown oxide, quite regularly stratified; but the floor of the mines being covered by water, it could not be critically examined. It is capped by black clay, richly impregnated with sulphuret of iron, which is overlaid by white and variegated clays and earth. Between the two mines the ore is wrought by drifts and gangways in various directions. As is usual at the larger mines, the ore from both of these pits is raised by steam-power up an inclined plane. Hoffman's Mine, wrought for the Allentown furnaces, was not in operation at the date of our visit. Kern & Albright's, leased by the Crane Iron Company, yields from 9000 to 10,000 tons per annum. From these mines the surface slopes gently S.E. towards the Jordan, and is deficient in rock-exposures; on the N.W., however, we find the limestone dipping S.E., beneath the ore of the Hoffman pit.

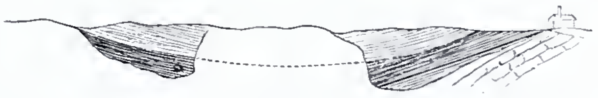


FIG. 580.—Kern and Albright's and Hoffman's Mines, near Siegerville.

At Siegerville an ore-pit was opened some ten years ago by Mr Sieger, and has been wrought by several iron companies, but is now abandoned. There is evidently a large body of valuable ore at this point, but the dilapidated condition of the mine prevented an inspection of its bedding or thickness. The dip is said to be N.W., and 68 feet depth of mining did not reach any rock-floor. The excavation extends over $\frac{1}{3}$ of an acre.

Xander's old bank, the property of the Crane Iron Company, is $\frac{1}{3}$ of a mile N.E. of Siegerville. This mine has not been wrought for six years, and is now in ruins. The ore, which is of the usual dark-brown hæmatitic variety, formed a bed dipping N.W., of a thickness varying from 12 to 20 feet. It was overlaid and underlaid by silicious pebbles. The position of this mine is near the boundary of the Auroral limestone, and the overlying Matinal slates, although these rocks are not found *in situ* in the vicinity of the mine.

Jos. Balliot's Mine and *Mickle's Mine*, separated from each other by the roadway, are situated 3 miles N.E. of Siegerville, and within one-fourth of a mile of a range of hills formed of the Matinal slates. In the former and larger pit the ore is almost exclusively of the brown variety; in the latter it is of a bright-red colour, and more crumbly character. The bottom of the deposit has not been reached. The bedding of the ore is horizontal. Beneath the upper stratum of brown ore in Balliot's pit reposes a band of black clay containing occasional masses of brown ore. These mines are very wet.

Stephen Balliot's and *Jeter's Mine* (formerly Shierey's) at Ironton, one-fourth of a mile N.W. of Jos. Balliot's, is a large excavation. From it the surface slopes gently S. towards Copley Creek; within a quarter of a mile N.W. the boundary of the Matinal slate ranges along the conspicuous ridge above-mentioned. This, as well as the other mines in the neighbourhood, seems therefore to lie among the alternating slate and limestone strata of the two formations. The gently-rounded surface of the hills, and the entire absence of rock-exposures, make it impossible to say under what precise conditions the ore has been deposited, with relation to the character and inclination of the subjacent strata. The nearest exhibition of rock displays limestone dipping N.W. towards the slate range at a moderately high angle.

The ore of this mine is of the usual brown hæmatitic variety, and is frequently quarried out in large masses; over the more solid body of the brown ore there is usually about 10 feet thickness of a more cellular honeycomb ore. The extreme depth of the pit is 50 feet, and ore has been mined throughout the distance. The floor of the deposit was not reached by a well sunk 16 feet from the deepest part of the mine. In a neighbouring smaller pit, belonging to Mr Balliot, both brown and red ore are obtained, though from different parts of the mine. The brown ore has a bedding which inclines 45° S.E. The ore-deposit at these mines is evidently a most extensive and valuable ore; but, as at present wrought, the annual yield does not exceed 4000 tons. Between it and Ritter's pit, a fourth of a mile farther N.E. along the same range, ore may be traced on the surface, and has been proved at several points. The continuity of the deposit between the two may perhaps be interfered with by a gentle rise prolonged from a knoll of limestone.

Ritter's Mine, leased by the Crane Iron Company, displays a fine body of brown hæmatite ore, varying from 30 to 40 feet in thickness, except at the outcrop, where the deposit is 12 feet thick. The dip is N.W., undulating at an average angle of 30°. The floor is of clay. Over the good ore the black clay is found capped as usual by white clay and surface materials. The depth of the pit is 45 feet, and its yield 6000 tons per annum. The limestone forming the lower slope of the slate hill dips S.E. towards the mine.

The slate ridge which forms the boundary of the valley of the Auroral limestone on the N.W. ranges S.W. from the vicinity we have last described, near the village of Foglesville in Upper Macungy Township of Lehigh County. Two miles S.W. of Foglesville it deflects S., and then N.E. for a mile as a spur, which courses S.W. as the general boundary of the limestone. The little cove of limestone thus enclosed is the seat of several rich deposits of hæmatite ore, which are extensively mined.

Sclough's Mine is situated $1\frac{1}{4}$ miles S. of Foglesville, at the N.E. end of the slate ridge to which we have just adverted. E. and S. of it the soil is all of limestone origin. The mine, though quite small, being recently opened, is interesting, as showing the hæmatite ore in several stages of development. At the pit the ore is a compact rocky brown and black hæmatite, graduating into a more rotten brown ore and ferruginous clay. In the trial-shafts sunk W. of the mine, the ore became more and more slaty, receding from the main body, and assumed the character of a rotten ferruginous slate quite valueless as an ore. The bedding of the ore has a gentle S.E inclination. The limited explorations that have been made do not warrant any judgment as to the extent or depth of the deposit. In the well sunk for water near the pit to a depth of 64 feet, black carbonaceous slaty limestone was encountered 36 feet beneath the surface, and continued to the bottom.

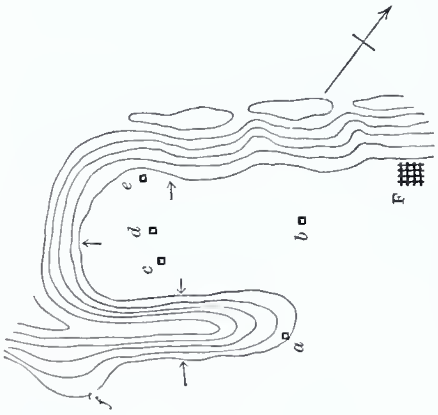


FIG. 581.

Haine's Pit is a small excavation three-fourths of a mile S.W. of Foglesville: it is now abandoned and in ruins. The ore is quite slaty in character, and apparently not abundant.

Miller's Mine is in the limestone cove S.W. of Foglesville. Like all the others, it is an open pit, from which the ore is raised by a slope plane and steam-engine. Its depth is 35 or 40 feet, extending over half an acre. There is a covering of from 5 to 25 feet of slaty debris over the irregularly-stratified ore. The bedding of the latter dips at a moderate angle S.E., but in that direction the ore rises to the surface again 100 yards distant, and was formerly wrought at the outcrop. As the bed sinks from the surface along the dip, the ore becomes more and more solid; but at places in the mine it is replaced by bodies of clay. A well sunk from the bottom of the pit to a depth of 18 feet, proved ore throughout that distance, though becoming lean at the bottom. The yield of this mine is about 2000 tons per annum. Leased by the Crane Iron Company.

Laurish's Mine, a few hundred yards W. of Miller's, is a small excavation not now wrought. Many fragments of the ore look not unlike a merely ferruginous slate externally, but when broken exhibit a close-grained brown hæmatite. The mine has been wrought for the Allentown furnaces.

Lichtenwalder's is an old pit lying close to the ridge of slate which bounds the cove on the W., and one-fourth of a mile from the last mine. The extreme depth of the pit is 55 feet. In some places the ore, all of which is a brown hæmatite, cavernous and velvety, is 40 feet beneath the surface, and at others it approaches and even outcrops upon it. There is no apparent or regular dip in the bedding of the ore, but the mass has a general inclination S.E. In parts of the mine white clay overlies the ore; in other parts surface materials are intermixed with it, in which cases washing is resorted to. The solid and softer ores are irregularly intermingled. From the deepest part of the mine, a well reached the clay bottom of the deposit at a depth of 14 feet. Yield, 3000 tons per annum. Ore delivered to the Crane Iron Company.

It is worthy of remark that in all the hæmatite ore-pits hitherto described, frequent cavernous, amorphous masses of flint rock are found disseminated, chiefly among the clays and softer ores. We also notice in the undecomposed calcareous slates which occupy the ridges bordering the ore districts, numerous crystals of sulphuret of iron.

Breinig's Mine is an old pit, now but little worked, on the S.W. prolongation of the slate range from Selough's Mine, 2 miles N.W. of Breinigsville.

There is no appearance of any stratification in the ore, but it is disseminated through ferruginous earth, which is washed, and the ore picked out. The mine is in confusion.

Two miles N.E. of Trexlerstown are the mines of *Gachenbach* and others, formerly known as *Shoemaker's Mine.* There are several pits upon the same great body of ore, which dips rapidly (45°) towards the S.E. The ore bed has a thickness of 42 feet at the pit, including the interstratified clays: it is exclusively red hæmatite, becoming harder and more rock-like as it gains cover. At the main pit, from which ore is now raised, it has a covering of 25 feet of surface-earth and clay. This pit is 50 feet deep, but ore has been proved 24 feet below the level of the mine resting upon a cavernous limestone. All the limestone near the mine dips S.E. There is no appearance of slate. Yield, 2500 tons per annum.

Wickert's Mine is situated 1 mile E.S.E. of Texas, in Lower Macungy Township, and about 2 miles from the range of the South Mountains. The soil is underlaid by limestone, and the ore is obtained from shallow pits, and by stripping the surface. It is so mixed with clay and earth as to require washing to separate it from impurities. The ore, which is a rich brown and black hæmatite, is invariably found in small angular or formless fragments, and sometimes as hollow geodes. Occasional fragments of ferruginous slate and slaty ore betray its slaty origin, and the presumption is that the slate from which it was derived was interstratified with limestone. The locality is not now wrought, but it has yielded 2000 tons of ore.

A few hundred feet distant is a much deeper and more extensive deposit at *Gideon Andreas' Mine.* The pits have reached a depth of 20 feet, extending over one-third of an acre. Occasional masses of rich brown hæmatite are found, but the chief part of the ore is intermixed with ferruginous clays, which are washed. There is no appreciable or regular bedding of the ore. The precise yield of the mine we did not ascertain, but it probably amounts to 3000 tons a-year.

In the same immediate neighbourhood are *Yobst's*, *Christian Andreas'*, and *Weygandt's* open-pit mines. In all of these the ore is washed from ferruginous earth, with which it is so intimately associated that the uninitiated eye would fail to detect its presence. The yield from the washing is about one-fourth or one-fifth part ore.

Schmoyer's and *Rheinhart's Mines* are three-fourths of a mile N.E. of those last mentioned. In the first of these there is no regularity in the bedding of the ore, and all the materials derived from the mine undergo washing. In Rheinhart's pit the ore-deposit is embraced in an undulating belt of 18 feet. In the wells sunk for water to wash these ores, limestone is invariably encountered at a considerable depth, but its dip we were unable to ascertain. The Schmoyer Mine yields about 1000 tons per annum, delivered to the Crane iron furnaces. The product of Rheinhart's pit, about equal in amount, is smelted at the Allentown furnaces.

Near by is an old mine, now but little wrought, known as *Mark's* or *Whiteley's.* The somewhat undulating deposit is 30 feet thick, and uniformly bedded.

Sigler's Mine, 2 miles N.N.W. of Mertztown, is situated near the base of a slate ridge which projects into the limestone valley from the great slate-range beyond. The mine has been wrought many years. The stratification of the ore is very confused and irregular, though there are some evidences of a general S.E. dip. In parts of the mine the masses of ore are found imbedded in clays, and are frequently so intersected by veins of quartz as to be rejected. The present yield does not exceed 1000 tons per annum.

There are several recently-opened small pits in the same neighbourhood, but they furnish nothing worthy of especial remark. In some of them the ore is brown hæmatite, in others red.

In the vicinity of Kline's store, and elsewhere along a narrow belt ranging with the valley, ore has been proved by surface-shafts and small pits at numerous points. All of the ore derived from these openings is of the silicious brown variety, in various degrees of purity. Many specimens appear rather as masses of rotten, ferruginous, and perhaps calcareous sandstone. These masses are generally large and cavernous, containing a yellow calcareous clay within. The excavations are too limited and superficial to afford us any insight into the structural features of the limestone strata beneath these deposits.

Trexler's Mine is 1 mile S.E. of Breinigsville. It is but recently opened, and the excavation has not proceeded far, but fine large masses of brown and red hæmatite are found plenteously scattered through the rich ferruginous earth, which is washed to obtain the smaller fragments. The disintegration of the underlying rock has been deep, as is proved by a well 80 feet in depth, wherein no solid rock was encountered. The mine is upon the top of a broad undulating hill. The limestone of the neighbourhood dips S.E.

East of Trexlerstown, on the back of a broad ridge, and within a quarter of a mile, are five ore-pits; three of these are the property of Mr S. Albright, one belongs to Mr Sehmoyer, and one to Mr Yoder. The ore is obtained by stripping and washing the surface-earth. It is a brown hæmatite in small fragments. The deposit is underlaid by limestone, but the rock does not crop out at the surface, nor have the excavations penetrated to it. The ore from these mines, and from Trexler's pit, is delivered to the Thomas iron-furnaces at Hokendaqua.

On Samuel Albright's land, 1 mile S.W. of Trexlerstown, a similar deposit to those above mentioned is found. None of the ore-deposits last referred to furnish any local evidences of their origin.

The Saucon Mines, the most extensively wrought for ore in the district now under consideration, are situated 3 miles S.W. of Hellertown, on the county line of Lehigh and Northampton, near the Saucon Creek. They are within the limestone valley of the Saucon, which is bordered by the ridges of the South Mountains, known as the Lehigh Hills. These mines, the property of Messrs Bahl and Gangware, consist of two pits, one a narrow excavation 250 feet long and 30 feet deep; the other a somewhat circular and shallow pit. In both mines red hæmatite ore is found intermixed with the brown, the former in irregular nodules, the latter stratified, particularly in the long pit known as Bahl's. The two varieties are found in about equal proportions in this pit, the former usually scattered through blood-red and pink clays, the latter alternating with many-coloured clays, from grey to dark brown. Most of the ore obtained from Gangware's (circular) pit is of the red hæmatite variety, but it is probable the brown ore will be found abundant when the excavation has penetrated deeper. There is no uniformity in the bedding of the ore in this pit, whereas in Bahl's the stratification has a quite regular S.E. inclination. A shaft sunk in Bahl's pit to a depth of 60 feet did not reach the bottom of the ore-deposit, but in other places within a hundred yards, mine-shafts, from 40 to 70 feet deep, encountered nothing but clay. It would therefore appear to be a purely local deposit or nest of ore, in which the materials have been laid down with some regularity. N.W. of Bahl's Mine, within 200 yards, limestone crops out, and dips gently towards the mine. One or two smaller excavations have been made within a hundred yards S.E. of Gangware's, but they have not led to any very promising results. In one a small amount of dull-brown ore was found, in the other nothing but sand and pebbles, and masses of undecomposed sandy rock. In Bahl's and Gangware's pits, fragments of rock are found undecomposed, chiefly a cherty material of greyish-blue colour and flinty texture. In the latter pit a large amount of this is found, but it was too nearly covered to admit of any conclusion respecting its true place or its dip.

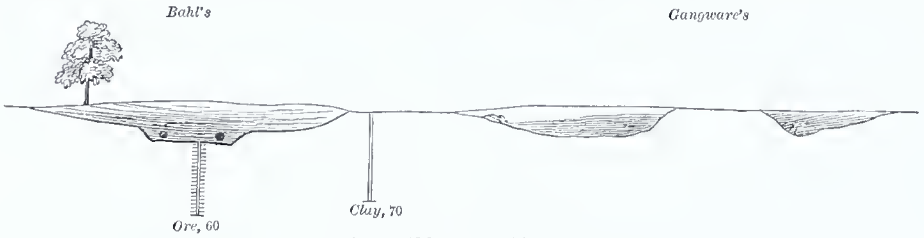


FIG. 582.—Ore Pits.

The yield of these mines is 15,000 tons per annum. The ore is delivered to the Thomas ironworks.

Moselem Mine, Berks County, 6 miles W.S.W. of Kutztown.—At this locality there are two pits, an Eastern and a Western, 200 yards asunder, situated in a narrow valley between a conspicuous slate-ridge and a lower limestone hill, in both of which the dip is N.W., the limestone passing under the slate. The E. mine is wrought chiefly for the supply of the furnaces of Seyfert, M‘Manus, & Co., at Reading. The surface excavation is not large, and the ore is found in confused and irregular bunches of a few inches thickness up to 20 feet; it is intermixed with clay and earth. The ore is now obtained, in great measure, from a series of gangways diverging from a shaft at a depth of 120 feet. The ore is a brown compact hæmatite of the average quality, in lumps large and small. The annual yield of the mine is 10,000 tons of ore, raised at a cost of $1.50 per ton.

The W. mine is exclusively an open pit, excavated 80 feet deep over half an acre. The ore is delivered to the Leesport furnaces, 9 miles above Reading. As at the former mine, the ore is found in irregular nests, and requires to be excavated and washed before it is fit for the furnaces. Yield, 12,000 tons per annum; cost of mining, $1.30 per ton under ordinary circumstances. In both of these mines, but especially the latter, many fragments of slate and cherty limestone are found only partially converted into ore.

Jefferson Ore-bank, 5 miles N.W. of Reading, worked by Eckert and Brother.—This locality of brown hæmatitic ore is situated on the E. side of a hill of the Matinal-slate formation, which occupies a position within the general valley of the Auroral limestone. The ore-deposit lies within 300 yards of a narrow dyke of trap, which ranges N.E. and S.W. through a considerable distance. The general bedding of the mass dips W., or under the hill, at an angle of 30°. In thickness it varies from 2½ to 15 feet, and is underlaid at the outcrop by about 10 feet of clay, beneath which the limestone is in place. In other parts of the mine the ore is in immediate contact with the rugged floor of outcropping limestone.

The pit is an open cut, stripping the surface materials from the ore stratum. The extreme depth of the mine is 63 feet, and the ore has been mined along the outcrop for 150 yards.

A large amount of ore has been obtained in the lower ground, the surface materials of which are washed. Black oxide of manganese is found as a thin stratum, sometimes 6 inches thick in the clay, 1½ feet above the ore. Yield of ore per annum, about 3000 tons.

To exhibit the furnace yield of these ores of the Kittatinny Valley as they are smelted, under the most favourable circumstances, the following details are presented of the dimensions and production of the *Crane Ironworks* at Catasaqua, on the Lehigh River, 3 miles above Allentown. They embrace five furnaces of the following dimensions:—

No. 1. Height of stack, 45 feet; diameter of bosh, 11 feet.
No. 2. „ 45 feet; „ 13 „
Diameter of hearth at tuyeres, 7 feet 6 inches.

No. 3. Height of stack, 48 feet; bosh, 16 feet; hearth, 8 feet 6 inches.
No. 4. „ 55 feet; „ 18 feet; „ 9 feet.
No. 5. „ 55 feet; „ 18 feet; „ 9 feet.

Three furnaces are (December 1857) in operation (Nos. 3, 4, and 5). The fuel used is anthracite coal from the Lehigh region, and the blast is heated to 600° by the waste gases of the furnaces. The number of blowing engines available for use is seven: the largest of these, a new engine, is rivalled only by the great engine of the Lackawanna Ironworks at Scranton. The diameter of the steam cylinder is 54 inches, and of the blowing cylinder 93 inches, each 10-feet stroke. Two fly-wheels are attached to the shaft, each 27 feet in diameter, and weighing 30 tons.

The total product of four furnaces, in the year 1856, with the materials employed, is appended:—

First 6 months, Coal, 29,831 tons; Ore, 31,970 tons; Limestone, 17,171 tons=Iron, 13,770
Last 6 months, Coal, 38,070 tons; Ore, 37,609 tons; Limestone, 19,757 tons=Iron, 17,322
67,901 69,579 36,928 = 31,092

The ores employed are the usual hæmatitic varieties of the district, mixed with one-fourth part magnetic ore from the vicinity of Dover, New Jersey. The product in pig-metal consists of iron, Nos. I., II., and III., the latter small in quantity.

It appears from the above statement, that of the mixed ores 2.237 tons are competent to the production of 1 ton of metal, a yield from the ore a little exceeding 49 per cent.

ANALYSES OF SPECIMENS OF HYDROUS PEROXIDE OF IRON, OR HÆMATITE, OF THE AURORAL LIMESTONE, PENNSYLVANIA.

LOCALITY.	Peroxide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 parts.	DESCRIPTION OF THE ORES.
Near Conshohocken, ...	71.50	0.50	2.55	14.30	11.0	...	0.15	49.75	Brown, cellular and ochry.
Hartman's, Northampton County, .	65.60	...	1.0	17.82	14.98	...	.60	45.92	Chestnut-brown, porous and crumbly.
Brotzman's, Northampton County, .	71.72	0.70	...	16.50	11.03	...	...	49.78	Mammillary, brown, with specks of silicious matter.
Dillinger's, Hellertown, . .	85.71	1.50	a trace	1.50	11.74	...	...	59.42	Brown, compact and also fibrous.
Rice's, 5 miles N.W. of Bethlehem,	70.25	a trace	1.55	16.40	11.40	...	.40	49.17	Porous, cellular and brittle (30 feet from the surface).
Rice's, same locality, . . .	79.12	...	1.56	4.80	13.98	...	.54	55.38	Stalactitic, brittle, chestnut-brown colour (50 feet below the surface).
Richards's, Northampton County, .	71.72	10.42	a trace	4.12	13.21	...	.53	49.72	Brown and bluish, somewhat nodular.
Moyen's, 4 miles N.W. of Allentown, ...	72.17	a trace	1.50	12.30	14.00	...	.03	50.51	Chestnut-brown, compact.
Moyen's (same mine as the above),	79.21	...	.75	7.50	11.0	...	.54	55.44	Stalactitic, pipes adhering, a rich chestnut-brown.
Miller's Mine, 4 miles N.W. of Allentown, ...	86.59	...	a trace	3.08	11.31	...	...	60.04	Brown, stalactitic; cavities between the pipes containing yellow peroxide oxide.
Balliot's Mine, 5 miles N.W. of Allentown, ...	83.22	...	.21	4.81	12.40	...	...	57.61	Colour liver-brown, compact and crystalline, the latter kind analysed.
Goetz's, 5 miles N.N.W. of Bethlehem, ...	84.0	...	a trace	4.10	11.60	...	.30	58.80	Blackish-brown, lustrous and resinous, compact, conchoidal.
Shwartz's, ½ mile S.W. of Emmaus,	79.64	...	a trace	9.05	11.40	...	...	55.22	Dark brown, compact, shining.
Albright's, S. of Trexlerstown, .	82.0	...	a trace	5.32	12.25	...	.43	57.40	Red hæmatite, and brownish compact ore.
A mine, 1 mile W. of Trexlerstown,	87.12	...	0.40	2.30	10.90	Sulphur, a trace.	...	61.03	Brown, compact, and stalactitic; a "pipe ore."
Breinig's, 1 mile N.W. of Breinigsville, ...	75.54	...	a trace	11.90	12.15	...	.41	52.87	Blackish-brown, compact; surface velvet-like.
Xander's, Lehigh County, . .	77.23	a trace	2.75	5.80	13.92	Lime, a trace.	.30	54.06	Brown with bright-yellow spots; cellular and brittle.
Moseler Mine, 4 miles S.W. of Kutztown, ...	77.20	...	2.60	8.90	11.00	...	.30	53.53	Dull brown, compact.
Gorgas Mine, 3½ miles S.W. of Harrisburg, ...	77.20	a trace	2.72	4.80	15.15	...	.13	54.04	Dark brown, hæmatitic.
Kerr's Fields, 8 miles W. of Carlisle, ...	69.0	...	4.8	13.0	13.0	...	.2	48.03	Dark chestnut-brown, compact and laminated.
Miller's Mine, 1½ miles from Miller's Furnace, Cumberland, . .	84.60	...	2.50	3.89	8.70	Lime, a trace.	.31	59.22	Chestnut-brown, stalactitic pipes slender; some of the ore compact.
Helm Bank, Cumberland County, .	77.2	...	2.0	5.8	14.5	...	.5	54.04	Cellular and mammillary.

TABLE OF HÆMATITIC IRON-ORES OF THE AURORAL LIMESTONE—*Continued.*

LOCALITY.	Perox-ide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
Clippengea Bank, Mary-Ann Furnace, Cumberland County, . .	87.09	...	.50	2.60	8.81	...	1.0	60.96	Chestnut-brown; stalactitic pipes, large.
Kresler Bank, Southampton Furnace, Franklin County, . . .	75.0	a trace	2.9	9.0	13.0	...	.1	52.5	Mottled-brown, amorphous, cellular, and somewhat laminated.
Railroad Bank, used at same Furnace, ...	72.0	a trace	.8	14.7	12.0	...	.5	50.4	Brown, cellular, and compact.
Pilgrim Bank, N.E. of Shippensburg,	77.7	...	4.0	6.8	11.0	...	.5	54.39	Dark chestnut-brown; stalactitic pipes almost obliterated.
Roxbury Bank, W. of Shippensburg,	75.1	...	3.6	9.3	12.0	...	...	52.57	Pipe ore, the pipe adhering; yellow hydrous oxide in the insterstices.
Green Village Bank, Franklin Co., .	82.6	...	0.9	4.2	12.0	...	.3	57.82	Brownish-yellow, long aud slender pipes.
Heifner's Bank, Caledonia Furnace, Franklin County, . . .	76.6	a trace	a trace	10.8	12.5	...	.1	53.62	Bright chestnut-brown, compact.
Heifner's, 6 miles from Caledonia Furnace, ...	81.6	...	a trace	6.7	11.4	...	.3	57.12	Brown; pipes closely adhering.
Middauer's, 3 miles N.E. of Waynesburg, Franklin County, . . .	72.6	a trace	0.5	14.0	12.5	...	.4	50.82	Brownish-red and purplish, compact, slightly resinous.
M'Dowell's Bank, 5 miles N.E. of Mercersburg, ...	83.60	a trace	1.50	4.80	9.40	Arsenic, a trace.	.70	58.82	Bright brown, amorphous, and cellular. This is called "garlic ore."
Carrick Furnace, Perth Valley, Franklin County, ...	59.50	8.30	5.80	17.40	8.80	...	.20	41.65	Nodular, surface mammillary, argillaceous specks.
Carrick Furnace, another specimen,	84.30	...	2.25	3.80	8.85	...	.80	59.01	Dark chestnut-brown, cellular, cells coated with a yellow ochreous deposit called "honeycomb ore."
A mine ¾ of a mile S.E. of Greenwood, in Kishicoquillas Valley, .	82.88	...	0.53	4.21	12.38	...	...	57.47	Brown, interstices lighter coloured, hard, granular, and porous, grains compact.
Bull Bank, Pennsylvania Furnace, Centre County, ...	86.40	a trace	a trace	2.30	11.00	...	.30	60.48	Chocolate-brown, hæmatitic, somewhat mottled, compact, fracture conchoidal.
Old Pennsylvania Furnace Bank, Centre County, ...	82.2	a trace	a trace	5.3	12.0	...	.5	57.54	Dark chestnut-brown, stalactitic; pipes small, and closely set.
Pennington Bank, 2½ miles S.W. of Warrior's Mark Town, . . .	76.50	2.70	...	7.50	12.50	...	.80	53.50	Chestnut-brown, compact, and cellular, coated with red oxide.
Pennington Bank, same locality, Huntingdon County, ...	84.80	...	1.50	3.00	10.0	...	.70	59.36	Rich brown, compact, and close-grained, rather columnar.
Pond Bank, Pennsylvania Furnace, Huntingdon County, ...	76.50	...	2.55	11.40	9.10	...	.45	53.55	Rich brown, closely adhering slender pipes, brittle.
Springfield Furnace Ore-bank, Morrison's Cove, ...	79.06	3.0	0.3	4.8	12.0	Lime, a trace.	.3	55.72	Dark brown, cellular, the cells coated with a bluish-black glaze.
Bombshell Bank, Rebecca Furnace, Morrison's Cove, ...	84.22	.41	0.65	6.43	8.25	...	...	58.95	A section of a hollow geode or bomb, fibrous hæmatite.
Red Bank, 3 miles S.W. of Rebecca Furnace, Morrison's Cove, . .	57.2	...	a trace	32.1	9.8	Lime, a trace.	.9	40.04	Bright reddish-brown, compact, and jaspery.
Sarah Furnace Ore-bank, 4 miles S. of M'Kee's Gap, Morrison's Cove,	76.5	a trace	a trace	11.7	11.6	...	.2	53.55	Blackish-brown, cellular and concentric layers of hæmatite.
Hillman's Mine, near Marble Hall, Montgomery County, ...	77.10	a trace	1.25	10.25	11.5	...	...	54.0	Brown, cellular, and compact; fracture rough.
Mine near Margaretta Furnace, York County, ...	72.20	1.0	2.50	11.25	12.5	...	.55	50.25	Brown, compact, surface ochreous; has a rough and sandy aspect.
Swartz's, 2 miles S.W. of Hanover, York County, ...									

TABLE OF ANALYSES OF IRON ORES OF THE MATINAL SLATES, PENNSYLVANIA.

LOCALITY.	Perox-ide of Iron.	Oxide of Manganese	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
M'Naughton's, 1½ miles W. of Mercersburg, ...	69.60	...	.73	9.20	20.0	...	.47	48.72	Dull brown, cellular (a bog ore).
Lourey's Knoll, Hanover Ore-bank, 2½ miles N.E. of Hanover Furnace, Bedford County, . . .	80.20	a trace	3.20	2.80	12.90	...	.90	56.14	Dark chocolate-brown, compact, and semi-crystalline.
Hanover Ore-bank, another (specimen), ...	73.6	a trace	2.0	11.5	11.5	Lime, a trace.	.14	51.52	Dull brown, compact, a greenish-black, blotches on the surface.
Hanover Ore-bank (a poorer specimen), ...	36.71	a trace	14.46	32.36	16.47	...	...	25.45	Brick-red and opalescent, brittle and granular.

CHAPTER IV.

IRON ORES OF THE SURGENT SERIES.

In the detailed description which I have given of the Surgent rocks, the series was shown to contain generally two, and in some localities three or four, separate beds of the peroxide of iron. The several horizons which these occupy have been pointed out, and their features and dimensions given at their numerous outcrops. Two of these layers of ore, the so-called "Fossiliferous Iron-ore" of the Surgent ore-shales, and the "Hard Ore" of the Surgent iron-sandstone, are almost coextensive, as we have seen, with the entire range of the Surgent formation throughout the Appalachian Chain in Pennsylvania, rising to the surface in each of its many belts. A careful study of the same series in other States has enabled me, with the aid of Professor William B. Rogers, to identify both of the above-mentioned beds of ore in numerous lines of outcrop far beyond the limits of Pennsylvania, in Western New York in the one direction, and through Virginia, as far as the Cumberland Gap, in Tennessee, in the opposite.

All of these bands of ore retain their special features and composition throughout the immense space which embraces them, with a constancy which is very remarkable, and from which we must infer a very wide diffusion and equality in the formative actions which produced each thin and well-characterised layer. They are variable, of course, in their thickness, and only in particular districts attain the dimensions, and possess the degree of richness which confers an economical value on beds of ore. But where they are thus developed—as, for example, in Montour's Ridge—they embrace, as we have seen, an extraordinary mass of mineral wealth.

These regularly-bedded ores of the Surgent series are to be regarded as among the permanent constituent strata of the formation, and as having originated, with the other sedimentary materials, in the form of very extended but thin sheets of ferruginous matter, covering at successive epochs the wide floor of the quiet Appalachian sea. Whence all the oxide of iron was derived which mingled with the earthy deposits of clay, sand, carbonate of lime, and the fossils of these deposits, is a question which the present state of research scarcely enables us to answer. Perhaps we are authorised, from a consideration of the physical changes which seem to have occurred at the close of the Matinal period, to refer its origin to a wide expanse of newly-upraised land of Primal and Matinal sediments, impregnated with a certain proportion of ferruginous matter, and to suppose that these parts, freshly exposed to active erosion and waste by atmospheric agents, in supplying a part at least of the materials of the Surgent strata, contributed, by steady accumulation, a copious amount of the salts of iron in solution to the waters of the Levant ocean. We have only to imagine, in the next place, the operation of certain well-known chemical reactions, such especially as would arise upon the sudden introduction of calcareous matter, to perceive a sufficient cause for the extensive precipitation of a definite quantity of the iron in the form of the peroxide.

This explanation derives some countenance from the independent evidence afforded,—by the more calcareous and fossiliferous nature of these ore-beds, compared with the strata which embrace them,—that the epochs of the deposition of the iron ore were also the periods of most copious supply of carbonate of lime.

To this source we may ascribe, with some probability perhaps, a large portion of the peroxide of iron in these layers; but we must not overlook another train of causes, operating since the elevation of the strata, to contribute in certain situations an increased supply of this ingredient. An enormous quantity of ferruginous matter, both in the shape of sulphuret and peroxide of iron, is diffused throughout the substance of the slates, shales, and marls in contact with these layers of ore; and the infiltering waters have probably conveyed some of this, chiefly in the condition of sulphate of iron, into the ore-bed, where the carbonate of lime of the fossils would convert it into the peroxide. That such has been the origin of a part of the iron in the "fossiliferous ore" of some localities, is indicated by the general richness of the ore in peroxide, in all situations where the position of the outcrop, the slope of the ground, and the thickness of the covering slate, are favourable to a copious infiltration of the surface-water.

But I must here advert to another much more instrumental cause of inequality in the proportion of iron, compared with the other constituents—I mean the *removal*, by infiltrating water, of a part or all of the soluble portion of the ore, chiefly its carbonate of lime, both diffused and in the shape of innumerable organic remains. The fossils, chiefly shells and joints of the Crinoidea, constitute in many instances fully one-half of the weight of the ore in its original unaltered condition, as the reader can ascertain by inspecting the Table of Analyses of the Surgent Fossiliferous Ores, and comparing the amount of carbonate of lime of the compact specimens with that of the soft or porous ones. It is obvious that a given bulk of the ore must retain, after the abstraction of this large quantity of calcareous matter, very nearly twice its former per-centage by weight of its principal ingredient, the peroxide of iron. A study of the circumstances which chiefly influence or control this dissolution of the carbonate of lime is therefore of the highest practical importance, since only through a competent knowledge and application of these conditions to his particular localities can the proprietor of a tract of this ore foresee the relative amount of the soft or chiefly valuable variety which his ground is likely to contain.

The whole value of the Surgent ore-beds, so far as the quality of the fossiliferous ore is concerned, depends upon the depth *below its outcrop* to which the dissolving process has extended; for experience has now confirmed the views which I ventured to express in my annual reports, that the stratum cannot be profitably mined, in the present condition of the iron manufacture, much below the level to which this surface action has penetrated.

What, then, are the conditions of outcrop that principally promote the thorough and extensive filtration of the waters along the slope of the ore stratum? The most favourable state of things is a coincidence in the dip of the ore-bed with the inclination of the ground above it. In this case, nearly the whole of the rain which falls upon the hill-side finally penetrates to the layer of ore, and, passing through the thin covering of slates, carries with it an additional amount of oxide of iron. A strict parallelism between the ore-bed and the surface seldom prevails over any considerable tract, almost never on the side of an anticlinal or monoclinal ridge, and scarcely anywhere but at the end of a broad anticlinal ridge like that which terminates Montour's Ridge east of Bloomsburg, where there is a truly extraordinary quantity of the softest and richest ore arching the point of the hill in a gentle curve, and nowhere overlaid by a thicker covering than from 10 to 20 feet of the slate. Where the dip of the ore is considerably steeper than the slope of the surface, the thickness of the overlying rocks rapidly increases as the bed descends, until its mass becomes too great to be penetrable by the atmospheric waters. In all such cases the ore, as we trace it downwards, grows progressively less soft, porous, and rich in iron, more and more of the substance of the fossils remaining undissolved, until we reach a point at which the stratum is in its original condition, with its maximum quantity of the carbonate of lime, and therefore its minimum of peroxide of iron. It should be observed that this limit is by no means as far beneath the outcrop, even under the moderate dip of 30°, with the surface sloping 15°, as many persons imagine. Much observation along the ore-belts of Montour's Ridge and other districts, persuades me that, under these conditions, the soft ore ceases, on the average, at a distance of 30 or 40 yards from its actual outcrop. Where the bed of fossiliferous ore dips *into* the hill, or in a direction contrary to the slope of the ground, the surface-water flows across its outcrop without entering it, and the stratum in this case receives a very small supply of infiltering water, so that not unfrequently the ore is compact, and full of its organic remains, to within a few feet of the soil.

To those interested in the many iron furnaces now erected, which depend, in part at least, for their supply, and mainly for the quality of their iron, upon this admirable variety of ore, the following calculations, based upon the foregoing data, will not be without their value. Assuming the average thickness of the main bed of the fossiliferous ore to be 16 or 18 inches, each square yard of the stratum will contain about one ton; and if the average width of the breast of soft ore be taken at 35 yards, then one mile of continuous outcrop must furnish the amount of 61,600 tons. It should be borne in mind, however, that several circumstances, besides the mere relative slope of the ore and of the surface, may influence the amount of percolation, and produce locally wide deviations from the above estimated width of the soft outcrop ore. Such are especially any irregularities in the contour of the ground, in the form of ravines, or knolls and swells; and again, any local contortions or dislocations in the strata. In regard to the silicious ore-beds of the Surgent series, both those of the iron sandstone and the Surgent older slate, the quality of the ore is very uniform, being but little influenced by the accident of proximity to the surface. Possessing but few fossils, and only a comparatively small proportion of calcareous matter, these ores are not susceptible of the purifying process so essential to the so-called "fossiliferous ores;" and hence, as far as their richness in iron is in question, it is of small importance what way the strata dip in relation to the slope of the surface. The direction of the dip will much affect, however, the extent to which the outcrop of the bed may be uncovered, but can thus influence only to a trivial extent the facility and cheapness with which it may be mined. When the "hard ore" is of equal or nearly equal thickness with the "fossiliferous ore," and contains as much as 30 per cent of iron, it is obvious that it will long outlast the latter in most of the localities where at present they both abound. Not deteriorating materially as it descends, and outcropping higher upon the flanks of the ridges, in consequence of its holding a lower place in the series, the supply of this variety of ore may be regarded as liable to few fluctuations, and to be almost inexhaustible.

The average cost of mining the soft fossiliferous ore, at and near its outcrop, exceeds 2 dollars per ton, while that of removing the "block ore" of the iron sandstone is from 1.25 to 1.75 dollars per ton.

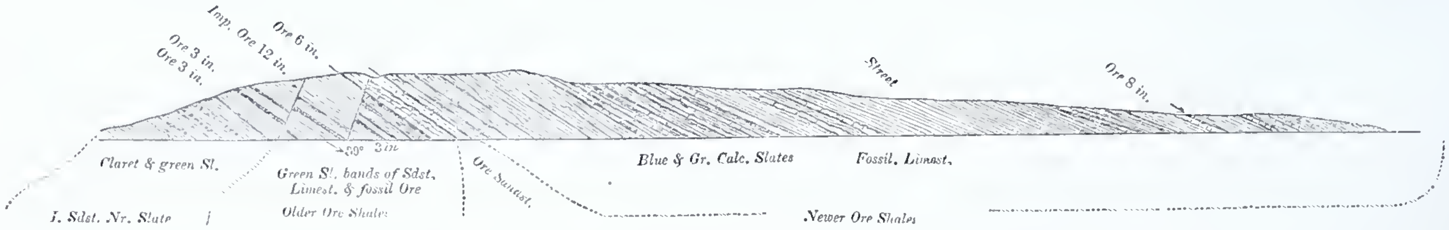


FIG. 583.—Surgent Fossiliferous Ore Group, Hollidaysburg, Blair County.—1 *inch* = 200 *feet.*

The accompanying section exhibits the fossiliferous ore group, or Surgent calcareous shales, under the type they assume near Hollidaysburg. It is taken from a railroad-cut near the town. The ore occurs, it will be seen, in very thin layers, and these are intersected by trivial faults.

ANALYSES OF SPECIMENS OF IRON ORE OF THE SURGENT SERIES, PENNSYLVANIA.

Locality and Variety.	Peroxide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insol. Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	Description of the Ores.
1. Smith's Gap, Kittatinny Mt., Dauphin Co., . . .	68.00	...	6.60	13.30	11.70	...	.40	47.06	Dark mottled-brown, coarse-grained, sandy-looking ore, imbedded in brown hæmatite.
2. Danville, Columbia County (Levant iron sandstone),	70.63	...	.57	23.77	2.57	Carb. of Lime, 2.46	...	48.97	Brick-red, somewhat fossiliferous, has the grain and aspect of a red sandstone. Called the "hard ore."
6. Danville (calcareous fossiliferous ore), . . .	30.34	a trace	...	2.64	1.80	Car. Lime, 62.43, Car. Mag., 2.79	...	21.03	Dark purplish-brown, slaty, micaceous, fossiliferous.
7. Bloomsburg (compact calcareous, fossiliferous ore), .	61.30	...	a trace	2.80	2.20	Car. Lime, 33.17	.53	43.00	Very similar to the last.
8. Bloomsburg (soft, porous, fossiliferous ore), . .	85.10	...	5.0	7.10	2.10	Carb. Lime, a trace	.40	60.00	Dark, reddish-brown, soft, gives a red powder, is full of pits and casts of fossils.
9. Laudisburg, Perry Co. (fossiliferous ore), . . .	76.45	1.50	1.25	14.40	5.70	..	.70	53.51	Dull brown, slaty, micaceous, highly fossiliferous.
3. Turtle Creek, Union Co., (Levant iron sandstone), .	37.64	...	a trace	59.0	3.20	...	.16	26.32	Pink colour, compact, coarse, and silicious, resembles the "hard ore" of Danville.
10. Mifflin, Juniata Co. (fossiliferous ore), . . .	70. 0	a trace	a trace	24.24	5.40	...	.40	51.10	Chestnut-brown, coarse, slaty, granular, micaceous, and fossiliferous.
4. Little Cove, Franklin Co., (Levant iron sandstone), .	30.38	...	1.20	67.0	1.42	...	...	21.06	Dark red and brown, granular and sandy, looks like a coarse red sandstone; is the "hard ore."
11. Little Cove, N.W. side, 4½ miles N. of Warren Iron Works (fossiliferous ore), .	83.0	a trace	6.0	5.3	5.1	Lime, 0.5	...	58.1	Reddish-brown, laminated, porous, fossiliferous.
5. Dickey's Mt., N.W. side, half a mile S.W. of Hanover Forge, Bedford Co. (Levant iron sandstone), . .	52.0	a trace	a trace	39.3	9.0	...	...	36.4	Dark brown, coarse, earthy; variety, Levant iron sandstone.
12. Matilda Furnace, near Jack's Narrows, Huntingdon Co.,	74.76	a trace	5.06	13.04	3.82	Lime, 1.35, undetermined matter, 2.11	...	51.84	Reddish-brown, powder red, porous, fossiliferous (upper part of fossiliferous ore).
13. Matilda Furnace (lower part of the same), . . .	44.07	a trace	1.39	52.33	2.62	Lime, 0.49	...	30.56	Brown, fracture rectangular, brown oxide of iron, cementing coarse grains of sand (lower part of fossiliferous ore).
14. Lick Hill, Woodcock Valley, Bedford Co. (used at Hopewell Furnace), . . .	46.50 part Carb. of Iron.	...	4.80	16.30	1.0	Car. Lime, 31.01	.39	27.72	Pale-red, highly fossiliferous; carbonate of lime of fossils visible.
15. Hopewell Furnace Mine, Bedford Co. (softest kind,)	78.05	.68	4.50	13.85	3.0	A trace of Lime	...	54.95	Brown, powder purple-brown, soft and brittle, fossiliferous, has some red micaceous oxide.
16. Hopewell Furnace Mine (same bed, compact kind), .	55.2	.5	1.0	8.8	2.5	Car. Lime, 31.4	.6	38.64	Reddish-grey; powder light brown; micaceous, fossiliferous.
17. Near Barre Forge, Huntingdon Co. (lower part of vein),	43.55 Prot. Carb. Iron, 3.56.	.50	.50	3.0	1.50	Car. Lime, 46.76	.63	32.2	Reddish-grey, fossiliferous; the fossils not all dissolved out.
18. N.E. of Barre Forge (average of the vein), . .	57.0	.60	1.40	7.50	2.0	Car. Lime, 32.10	...	39.9	

CHAPTER V.

IRON ORES OF THE PRE-MERIDIAN AND MERIDIAN SERIES.

The Pre-meridian and Meridian Series in Pennsylvania are accompanied by certain characteristic iron-ores, each having its own particular kind. The ore of the limestone is most abundant in Huntingdon and Bedford counties, but only in two or three localities does it exist in sufficient quantity to repay the pursuit. It is usually scattered in the soil overlying the limestone, in the form of compact lumps, having a laminated structure and a light chestnut-brown colour. The shallowness of the earthy deposit, resting upon the usually sloping surface of the formation, and the small amount of ferruginous loam in it, sufficiently account for the absence of large accumulations of the ore.

The Meridian sandstone exhibits a greater number of productive localities of ore. These seem to occupy two distinct positions in relation to the formation. One species of the ore is found in connection with the lower or more ferruginous portion of this porous stratum, usually near the junction of the coarser more arenaceous beds with the soft calcareous laminated yellow layers. It would appear to have been the product of filtration through the looser upper beds, the oxide of iron having been arrested and precipitated on coming into contact with the more impervious and calcareous layers beneath. Thus, in Chestnut Ridge, Huntingdon County, there is a bed of ore, about 2 feet thick, near Chester Furnace, occupying precisely the line of junction of these two members of the formation. Not unfrequently the ore is lodged in a body of ferruginous clay, near the contact of the limestone and sandstone, all the materials of which are, however, traceable to the sandstone. This is the position of a valuable ore-bed near Alleghany Furnace, 6 miles from Tuckahoe, in Huntingdon County, in which the ore consists almost entirely of the stalactitic variety, some of the stems or pipes being of great size and beauty. Much of this ore, from the lower portion of the Pre-meridian sandstone, is more or less manganesian: it contains more ore, in proportion to the surrounding impurities, than usually occurs in the ores of the Primal and Auroral formations.

Another variety of ore of this series is restricted to the upper limit of the sandstone, occurring not unfrequently precisely at the junction of this rock and the overlying Cadent black slate. It is not extensively developed in Pennsylvania, and is to be seen chiefly in the belts S. of the Juniata, especially in Bedford County. But in Virginia, and particularly among the ridges W. of the great valley in the James River region, it occurs in numerous and productive openings. It is there spread, in an almost continuous stratum, over wide areas, and marks very distinctly the junction of the sandstone with the slate. In many localities the mass consists of little more than the upper layers of the Meridian sandstone, strongly impregnated with peroxide of iron, and graduating into a material much too coarse and sandy to be of value in the smelting furnace. In Pennsylvania the better kinds of this ore are often in massive chunks, and are hæmatitic; but these chunks, when met with on the surface of the sandstone, contain in some localities much compact *chert*, which effectually destroys the usefulness of the ore.

The position of this ore, and the highly-pyritous character of the overlying slates, especially the layers in contact with the sandstone, point at once to the source of the oxide of iron, and render it needless to enter into chemical details, which would be but a repetition of the explanations already given.

TABLE OF ANALYSES OF IRON ORES OF THE PRE-MERIDIAN SERIES.

Localities.	Peroxide of Iron.	Peroxide of Manganese.	Silica and Insoluble Matter.	Alumina.	Occasional Ingredients.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Tuckahoe, Huntingdon County,	71.50	a trace	20.40	2.50	...	5.00	50.00	Brick-red, cellular, brittle.
Tuckahoe, Alleghany Furnace Bank, ...	69.80	a trace	18.40	2.30	...	8.70	48.86	Brownish-yellow; cells lined with pulverulent oxide.
Same locality, ...	82.20	8.00	6.00	a trace	...	4.00	57.54	Bluish - brown, earthy, compact, from near the base of Pre-meridian sandstone.
Same locality (pipe ore), . .	86.91	...	1.93	0.22	...	10.44	60.26	Pipe ore; stems large, surface iridescent.
One mile S.W. of Bell's Furnace, Tuckahoe, ...	73.28	a trace	12.88	5.52	...	9.38	50.81	Chocolate-brown, lustre resinous, makes a weak iron.

CHAPTER VI.

IRON ORES OF THE CADENT AND VERGENT SERIES.

The Cadent and Vergent rocks contain important bands of iron ore, differing essentially in their composition. They are limited to certain districts within the range of the formations to which they belong, nor do they occur together in the same region. The lowest of these ores is most fully developed in the Lewistown Valley, between Lewistown and the Southern State line, and in the belts adjoining it. It occupies a position in the Cadent lower black slate, only a few feet or yards above the calcareous beds or cement layers, and from 50 to 100 feet above the upper layers of the Meridian sandstone. Between the Juniata River and Maryland, in the localities where it has its maximum expansion, it varies in thickness from 3 or 4 feet to 10 or even 12 feet, having the form of a series of solid grey layers, separated by thin seams of slate. In its native condition, unaltered by the atmospheric action which has everywhere changed it at its outcrop, this ore is a ponderous, bluish-grey, or lead-coloured proto-carbonate of iron, sometimes breaking into square masses, and sometimes of a more slaty or laminated structure. It does not effervesce when touched with acids; when roasted, it becomes reddish-brown, and is then strongly attracted by the magnet. The analyses will display the prevailing composition of this ore.

It is only when the stratum has been long exposed at its outcrop to atmospheric action, converting it into the brown peroxide of iron, by which it assumes a wholly different aspect, that it has the form hitherto worked by the furnaces situated near it. This ore, at its outcrop, is of a dark hazel-brown colour, a smooth grain, and a cellular structure. That which is derived from the rectangularly-cleaving portion of the solid bed is in square masses, with large squarish cells, often glazed and iridescent on their inner surfaces, and either entirely empty or partially filled with a pure bluish clay. Sometimes, where the bed has been so protected as to have escaped extensive atmospheric action, this conversion to the brown peroxide is only partial, a solid nucleus of the bluish proto-carbonate forming the interior of the lump, while the peroxide occurs only on the surface, in the form of a crust of greater or less thickness. Between this crust and the undecomposed nucleus, the earthy particles originally in that portion of the proto-carbonate, which has been converted into the peroxide, having been deserted by the iron in assuming its new state of concretion, lie loose in the intervening space, and form a grey dust when dry, and, when moist, a tenacious clay. This travelling of the atoms of oxide of iron from the interior to the circumference of the mass, in all cases where a proto-carbonate of iron undergoes conversion to the peroxide, is a highly curious fact, not devoid of a practical as well as a scientific interest.

It is probable that this bed of ore extends, either partially or uninterruptedly, for considerable distances, in nearly all the synclinal basins where the lower beds of the Cadent series occupy the summits of the sandstone ridges between Lewistown and Shirleysburg. The ore-banks at present worked are in these positions. The ore occurs in Little Cove, and at Pennock's furnace, Huntingdon County, in precisely the same geological relations; but to what extent it prevails throughout the long line of intermediate country, nearly 35 miles in length, we have at present no means of ascertaining. The discovery of the true nature and exact position of this iron ore furnishes an interesting illustration of the utility of geological researches systematically prosecuted. The ore having been previously dug at the outcrop only at remote and insulated points, no general clue to its position, applicable in practice, had been detected, nor was it probable that any could be, until the order of superposition had been minutely and methodically studied. No sooner was this done, however, than we perceived that all the outcrops of the ore, accidentally discovered in the formation, belonged to one solid and extensive band, regularly interstratified in the lower part of the Cadent black slates, accompanied by such well-marked features in the adjoining rocks as to render the tracing of its course, with proper skill and knowledge, a matter of ease and certainty.

The ore of the Vergent series is a widely-distributed stratum, having a very continuous range through parts of Lycoming, Clinton, and Tioga counties, but not developed in any thickness in other portions of the State. Its place in the series is near the top of the Vergent shales, or more properly in the alternating group by which the Vergent and Ponent strata graduate into each other. It seems to attain its maximum thickness on Larry's Creek, in the Alleghany Mountains, where the principal bed is about 3 feet thick. East of Lycoming Creek it gradually thins away, and it also vanishes in the other direction at the Susquehanna, not being traceable beyond Farrandsville. It is found as far North as the Tioga River.—(See Vol. I. pp. 310, 311, for some detailed descriptions of it.) This ore is of a dull purplish-red colour, and is arenaceous and granular, the peroxide of iron encrusting the grains of silicious sand, so as to impart to it a somewhat oolitic aspect. It contains organic remains, chiefly two or three species of the bivalve shells characteristic of the upper part of the Vergent shales; but it is by no means as rich in fossils, and therefore in calcareous matter, as the fossiliferous ore of the Surgent series. A large excess of silicious matter in the ore greatly impairs its value for the smelting-furnace. This ore closely resembles the celebrated Cleveland ore of Yorkshire, England, a bed 14 feet thick in the oolite formation. Its qualities will be readily inferred from the analyses contained in the following Table :—

TABLE OF ANALYSES OF IRON ORES OF THE CADENT AND VERGENT STRATA OF PENNSYLVANIA.

LOCALITIES.	Carbonate of Iron.	Peroxide of Iron.	Oxide of Manganese.	Silica and Insoluble Matter.	Alumina.	Carbonate of Lime.	Water.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
Cadent Black Slate.									
Six miles W. of Pinegrove, .	...	37.00	...	45.90	4.20	1.50	11.25	25.90	Mottled-brown, slaty, cellular, fossiliferous.
Walter's Bank, ½ mile W. of Brookland Furnace, Lewistown Valley, . . .	...	66.00	a trace	18 80	5.80	...	9.00	46.20	Brown, hæmatitic, velvet-like.
Mercy's Bank, 1½ miles S.E. of Newton Hamilton, .	...	65.40	a trace	20.50	4.60	...	9.00	45.78	Dull-brown, laminated, cellular, and silicious.
¾ mile W. of Chester Furnace, Huntingdon Co., .	...	66.92	14.64	7.57	1.93	...	9.48	46.40	Mottled, dark brown, compact, soft.
Warren Ore Bank, Little Cove, Franklin County, .	...	67.60	a trace	18.80	a trace	...	12.70	47.32	Dark brown, hollow lumps.
Brown Furnace, Little Cove,	80.55	...	...	17.00	1.50	...	1.00	38.80	Bluish-grey, nodular, and compact.
Cadent Newer Shales.									
Two miles W. of Pinegrove,	...	32.00	...	60.00	0.50	1.00	6.00	22.40	Dull, reddish-brown, slaty, cellular, fossiliferous.
Lycoming Creek, front of Alleghany Mountain, .	...	48.80	a trace	49.38	a trace	a trace	1.68	33.83	Chocolate-red, powder red, fossiliferous, granular.
Larry's Creek, Lycoming County, ...	...	61.20	...	32.30	3.00	1.30	2.20	42.84	Purplish-brown, powder red, fossiliferous, sandy.
N.W. side of Big Scrub Ridge, 2½ miles S.W. of Bedford Turnpike, . .	...	84.54	...	2.85	a trace	...	12.00	59.17	Mahogany-brown, compact, hæmatitic (a surface ore).
Big Ore, base of Warrior's Ridge, Woodcock Valley, .	...	75.22	a trace	7.75	2.50	Org. Matter 2.80	11.45	52.65	Ochreous-brown, earthy, vegetable fibres.

CHAPTER VII.

IRON ORES OF THE UMBRAL SERIES.

The Umbral red shale of the bituminous coal region is accompanied throughout nearly its entire outcrop along the Alleghany Mountain, and towards the N.W., by a very peculiar variety of iron ore, which, in certain localities already described, is destined to become of much economical importance. This ore occurs high in the formation, usually not more than a few feet below the bottom of the Seral conglomerate. It is the grey and mottled carbonate of iron described in the chapter upon the Umbral strata. The ore is of somewhat various external features, but its most prevailing character is that of irregular knotty nodules of a mottled red and whitish or grey colour. These lumps, which are usually imbedded in a soft reddish shale, are often, especially near the outcrop of the stratum, coated with a brown crust of the peroxide of iron. On Lycoming Creek, the purer specimens of the ore, consisting principally of the crystalline carbonate of iron and silica, are internally of a pinkish-yellow colour, with a velvet-like aspect. In other districts, as that of Tioga River, near Blossburg, the ore is in regular continuous layers, certain parts of which are mottled, and have almost an oolitic structure.

It is only in certain local tracts of country that this interesting ore is rich enough in iron, and thick enough to be of value to the manufacturer of iron; but where it can be used, the metal procured from it is of remarkable excellence. The chemical nature and geological relations of this ore are very similar to those of the carbonate of iron of the coal strata, and the conditions under which it originated were obviously very nearly identical with those which produced that variety. I shall therefore reserve what I have to say respecting the source of the iron, until I come to speak of that of this still more important variety. Beside the nodular crystalline carbonate now described, the Umbral shales contain, especially in their S.W. outcrops, as in Somerset and Fayette counties, a species of ore identical with the ordinary compact or earthy carbonate of the Coal-measures. This latter kind belongs to a small subordinate group of coal-bearing rocks, which, in the districts mentioned, underlie the true Seral conglomerate, or constitute its lowest member, indicating a gradual transition from the Umbral series.

ANALYSES OF IRON ORES OF THE UMBRAL RED SHALES OF PENNSYLVANIA.

LOCALITIES.	Carbonate of Iron.	Peroxide of Iron.	Oxide of Manganese.	Carbonate of Lime.	Carbonate of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
Savage's Mines, Trough Creek, Huntingdon Co.,	...	88.09	...	...	...	a trace	...	...	11.0	69.93	Reddish-brown, compact, and jaspery.
Hopewell Furnace (Old Bank), Trough Creek, .	...	60.00	a trace	0.40	...	32.10	2.50	...	4.50	42.00	Red and brown, nodular.
Hopewell Furnace, Terrace Mount Mine, . .	...	84.00	a trace	...	...	2.30	a trace	...	13.50	58.80	Dull chocolate-brown, compact.
Ralston, Lycoming Co., .	65.00	...	...	0.72	...	28.80	1.00	...	4.28	32.06	Ash-grey, spathose.
Astonville, Frozen Mine, Lycoming County, .	68.00	...	...	0.60	...	28.70	0.80	...	1.50	32.80	Pinkish-yellow, velvet-like, minutely crystalline.
Farrandsville (Lower Red Shale), ...	...	68.40	...	a trace	...	25.60	3.60	...	2.00	47.88	Purplish-red, compact, nodular, sub-crystalline.
Johnson Hill, Blossburg, .	29.84	...	a trace	...	...	66.80	0.50	...	2.56	14.42	Light-grey, pinkish, spathose.
Bennett's Branch, 1½ miles above Warner's, Clearfield County, . . .	82.20	6.50	...	...	...	6.65	1.00	...	3.40	44.22	Dull-grey, compact.
Bennett's Branch, same locality, ...	63.80	...	1.00	...	...	30.90	0.75	...	2.75	30.28	Grey, light, compact, and coarser than the above.
S.E. of Blairsville, Indiana County, ...	37.80	...	...	5.50	7.50	37.80	7.60	...	3.50	18.27	Mottled-red and green, nodular, somewhat spathose.
Hill's, W. side of Chestnut Ridge, Indiana County, .	...	51.25	a trace	2.00	...	36.50	5.96	...	4.00	35.87	Cinnamon-brown, nodular.
Garey's Mine, Fayette Co.,	84.14	2.78	a trace	3.00	...	...	0.75	...	5.00	40.62	Dove-colour, externally brown, nodular, close-grained.
Garey's Mine, same locality,	35.50	...	...	2.50	1.35	15.55	2.80	...	2.00	38.22	Greyish-blue, kidney-formed, close-grained.
Chestnut Ridge, Pennsylvania Canal, Westmoreland County, . . .	...	61.50	...	a trace	a trace	31.44	1.25	...	5.20	41.05	Purplish-brown and greenish, jaspery.
Hare's Valley, Huntingdon County, . . .	...	97.54	...	...	...	3.12	0.18	...	...	67.63	Purplish-red, massive, micaceous, unctuous (a surface specimen).

There is still another, but much more local deposit of iron ore in the series, occupying the very horizon which separates the Umbral red shale from the underlying Vespertine conglomerate. This ore is limited to the synclinal basin of Trough Creek in Huntingdon County, where it has the form of massive lumps or nodules enclosed within the very lowest beds of the red shale. It is usually a very dense and compact form of the ordinary brown peroxide of iron, and for the most part contains too large a proportion of foreign matter, particularly silica and manganese, to permit it to yield a good cast-iron. When smelted alone, the product has invariably been a weak or "cold - short" metal. This ore has been derived apparently from the ferruginous matter diffused through the highly-coloured layers of shale in the inferior portion of the Umbral red shale. Another ore of the Umbral series is the interesting deposit seen in the valley of Stafford Meadow Brook, and which has been already sufficiently described at page 358 of this volume. It resembles the Trough Creek ore both in its chemical aspect and its stratigraphical position. The preceding Table displays the prevailing composition of the several ores here described as appertaining to the Vespertine series.

CHAPTER VIII.

IRON ORES OF THE COAL STRATA.

In the Coal-measures of Pennsylvania we meet with the proto-carbonate of iron, the characteristic iron-ore of the coal-formation, under a great variety of forms and minor shades of composition. The Table of Analyses of these ores will serve to exhibit the chemical constitution of the whole series, and to show certain important general differences between those of the different districts of our vast coal region. By an inspection of these numerical results, it will be seen that, as a class, our carboniferous ores contain but a small amount of alumina, and are therefore not entitled to be called argillaceous iron-ores: the analyses, on the contrary, make it apparent that their chief impurity is silica, the proportion of which on the average is not, however, materially greater than in the clay ironstones of Europe, although the amount of alumina is considerably less. The average quantity of silica is 23 per cent, and that of alumina 2.2 per cent. A very conspicuous and important difference is noticeable between the ores of the anthracitic coal - basins and those of the bituminous: the former are of a coarser texture, and for the most part less rich in iron, and this difference is principally owing to the presence of a larger proportion of silica and insoluble matter. In the anthracite ores the average proportion of silica is 28 per cent, while in the bituminous ores it is shown to be 18 per cent. From this greater preponderance of the silicious ingredient, these anthracitic ores are more difficult of reduction in the furnace, and demand a larger proportion of limestone flux. One main obstacle to their successful use, in some instances, arises from the firm adhesion of a portion of the surrounding shale to the surface of the nodules, the result of the cementing and indurating action to which all the rocks of the anthracitic region have been subjected from subterranean heat. Beyond the difference in the silica here referred to, there are no other essential points of disparity between the two classes of ores; both contain carbonate of lime in nearly equal proportion, and derive from the presence of this flux a partial corrective of the silica and other earthy impurities. Both of these groups of ores have among their constituents frequently two or three per cent of the carbonate of magnesia, an element which we might naturally look for in association with the carbonate of lime, when we reflect upon its general abundance in the several limestone formations, and the proofs they afford of the general prevalence of this ingredient in the ancient Appalachian waters. The carbonate of manganese likewise constitutes from one to three per cent of the weight of many of these ores, but this element and the carbonate of magnesia are seldom present in sufficient quantity to impede essentially the fusion of the mineral where a sufficiently copious blast is employed, and the fuel used is either coke or anthracite.

Of particular beds appertaining to this widely-diffused class of ores, two layers are sufficiently important and peculiar to merit in this place a special but brief notice. One of these is the so-called Blackband of the Bear Valley Basin, the geological facts respecting which have been already presented. In its chemical composition this ore differs in no very material point from the celebrated and very valuable blackband ore of Scotland, as any analysis of the latter will show. The sole injurious ingredient in the anthracitic blackband is its sulphur, but the considerable amount of "coaly matter" diffused through the ore will tend to facilitate the burning off of at least a part of this in the process of roasting.

Another feature of difference, but probably not a very important one, between the Pennsylvanian and the Scotch blackband, is in the bituminous nature of the coaly matter contained in that last named, and of which the anthracitic ore is necessarily destitute. This bituminous matter, by its diffusive flame and its constituent hydrogen, is perhaps the most efficient agent in the removal of any sulphur in such an ore that Nature could provide, and hence one reason of the general excellence of the blackband iron of Scotland.

The other layer of ore to which I wish to advert, is the much more extensive stratum appertaining to the lower Coal-measures of the bituminous series of Western Pennsylvania, and described in my account of that district as the limestone or buhr-stone ore. It is, as I have already amply shown, a regular and widely-extended stratum of the proto-carbonate of iron, of superior purity and richness. Overspreading, as it does, a wide geographical area in the fifth and sixth bituminous basins, embracing parts of the Clarion and Alleghany rivers, and a large portion of Armstrong, Venango, Clarion, Mercer, Butler, and Beaver counties, it has already,—since attention was first drawn to it as a continuous and traceable seam of ore, in my Fourth Annual Report,—become the basis of numerous and extensively-distributed ironworks, and is destined to be hereafter one main element in the future rapid march of wealth and manufactures in Western Pennsylvania. This ore consists generally of a mixture of the peroxide and proto-carbonate of iron, the latter predominating, except near the outcrop, where the ore is composed almost exclusively of the brown hydrated peroxide, and is of various tints of brown and red. Its structure is often cellular, the irregular cavities being surrounded by a thinner or thicker crust of the ore. In other instances, it occurs in large masses in which the ore is intimately mingled with the chert upon which it reposes, and is full of drusy cavities, lined with minute crystals of quartz, tinged red, brown, and pink by the oxide of iron. These cavities sometimes contain water. Though this seam of ore accompanies the limestone over considerable spaces of country, it is not strictly continuous, but occurs rather in large patches of various thicknesses. The bhur-stone and the iron ore would seem indeed to replace each other, the one most abounding where the other is deficient. For the chemical composition of this ore, see the analysis in the Table which follows. The great importance of this valuable deposit to the growing wealth and enterprise of the Western part of the State is beginning to be appreciated, I need hardly, therefore, dwell upon it farther than to mention the following circumstances in its favour: Its richness far exceeds that of the nodular variety common in the slate of the Coal-measures, and will bear comparison with much of the best ore found in the limestone valleys S.E. of the Alleghany Mountain. Another merit is the facility with which it may be smelted, either alone or when mixed with the nodular or ball ore, and particularly with the bog ore, found so abundantly in Venango and Clarion counties. In the thicker parts of the deposit it is a nearly pure semi-crystalline proto-carbonate of iron, a variety well known to be susceptible of extremely easy reduction. It is, morever, recommended by the readiness with which it can be traced, arising from its accompanying closely the fossiliferous limestone, which is an excellent landmark. The buhr-stone assists the discovery of it in a still greater degree, the fragments of that peculiar rock being so easily recognised. Besides these important facts, it should be mentioned that a workable seam of coal occurs above the ore and limestone, and another beneath them at a moderate interval. The importance of this triple association of the materials necessary in the manufacture of iron to the future wealth of our Western counties, must be obvious to every one who adverts to the incalculable advantages which Great Britain has derived from the same fortunate union.

The ores of the Coal-measures display at their outcrop two very distinct varieties as to their chemical composition—namely, the brown peroxide and the carbonate of iron—though it is more than probable that nearly all of the peroxide has been originally derived from the other kind. The carbonate, which is a compound of the protoxide of iron and carbonic acid, after long exposure to the air, absorbs an additional amount of oxygen, losing at the same time its carbonic acid, and is thus converted into the brown oxide or hæmatite. This change may be witnessed in all its stages in many of the more exposed beds, the nodules in some cases being merely coated with a thin shell of the peroxide, and in others altered to a considerable depth, leaving but a small central mass of carbonate; and again, in other instances, where the exposure has been still longer and more complete, the whole has been transformed into the brown ore.

The carbonate ore is invariably more or less calcareous, as already intimated, and in many cases contains so large a proportion of carbonate of lime as to be in fact a ferruginous limestone, a condition especially seen in the buhr-stone ore. When the above-described change has arisen, the ore is found to have lost the greater part of its original calcareous matter, and hence the resultant brown ore is comparatively exempt from that ingredient. To explain this effect, it is only necessary to advert to the solubility of carbonate of lime in the percolating surface-waters, and to the fact that the carbonic acid escaping from the carbonate of iron, in its conversion into the peroxide, would greatly aid in the solution and removal of the calcareous matter.

Respecting the origin of the carbonate of iron in these ores, it is sufficiently evident from the texture of the nodular ore itself, and of the slates surrounding it, that the whole mass of each ore-bearing bed was primarily deposited as a fine calcareous and ferruginous mud, in which was included a large amount of organic matter, especially the fragments of the carboniferous vegetation, and in some cases certain species of shells. In these deposits the iron was at first probably in the state of peroxide, as in nearly all finely-pulverised and long-exposed sediments. By the slow decomposition of the organic materials, a part of the oxygen of the peroxide would be withdrawn to combine with the carbon and hydrogen of the organic substances, and the iron would be thus left in the state of protoxide. At the same time the carbonic acid formed by the oxidation of the carbon would unite with the protoxide, and give rise to the proto-carbonate of iron. As long as any organic matter remained in the mass, this change would continue, and in this way the whole of the peroxide of the original sediment may be conceived to have been converted into carbonate. The same action now continuing, though in a slighter degree, must tend to protect the carbonate from the decomposing action of the atmosphere, and thus in many cases to retard its conversion into the brown oxide.

The nodular form of the ore is evidently a subsequent result, and must be referred to the agency of a concreting force among the particles by which the carbonates of iron and lime, previously diffused in a uniform manner throughout the mass, have been gathered around certain centres. Some of the superficial beds of brown ore resting upon the outcrop of the coal-rocks, would seem to be derived rather from the sulphuret of iron diffused in the adjoining slates, as in cases previously mentioned, than from the decomposition of the nodular carbonates.

These have nothing of the continuous regularity of the layers of the nodular ore, and they bear a strong resemblance to the loose ore-deposit of the older Appalachian slates.

In further elucidation of this interesting subject, I take the liberty of introducing here a valuable brief essay

ON THE ORIGIN AND ACCUMULATION OF THE PROTO-CARBONATE OF IRON IN COAL-MEASURES, &c.

BY PROFESSOR WILLIAM B. ROGERS.

THIS compound, as we know, where mined in the Coal-measures, presents itself in courses of lenticular nodules and interrupted plates usually included in carbonaceous shales, and in the fire-clays which underlie the seams of coal, and in such cases it often forms a heavy ore containing but little earthy or organic matter mixed with the proto-carbonate; but it is also frequently met with in a *diffused condition*, pervading thick strata of shale and shaly sandstone, and causing these rocks to present in their different layers all the gradations of composition from a poor argillaceous and sandy ore, to beds of sandstone and shale, with little more than a trace of the ferruginous compound.

On comparing the different subdivisions of a system of Coal-measures, we may remark certain general conditions connected with the abundance or with the comparative absence of the proto-carbonate in the strata.

One of these is seen in the fact that *the lenticular ores and strata impregnated with proto-carbonate of iron are in a great degree restricted to such divisions of the carboniferous rocks as include beds of coal, or are otherwise heavily charged with carbonaceous matter.* This is well shown on comparing together the four subdivisions of the carboniferous rocks of the great trans-Alleghany coal region, as classified under the head of the Seral Coal Series of the Pennsylvania and Virginia geology. In the first of these, designated as the older Coal-measures, the proto-carbonate is found in larger amount, both in the shape of layers of lenticular ore, and diffused through the substance of the shaly strata. In the next division above, distinguished as the Older Barren Shales, and which, as the name implies, is comparatively devoid of carbonaceous matter, much less of the proto-carbonate is met with. In the third group, that of the newer Coal-measures, the ore again abounds; and in the uppermost division or Newer Barren Shales, it has a second time almost disappeared.

The connection between the development of the proto-carbonate in the strata, and the presence, either now or formerly, of a large amount of carbonaceous or vegetable matter, becomes even more striking on a detailed examination of particular beds. Thus in the coarse sandstones of the Coal-measures which are comparatively destitute of vegetable remains, we find little admixture of the proto-carbonate. On the other hand, the fine-grained flaggy argillaceous sandstones, which are often crowded with the impressions and carbonised remains of plants, are at the same time more or less impregnated with this ferruginous compound. So again, the soft argillaceous shales, in the midst of which the lenticular ore so frequently presents itself, show by their dark colour and included impressions of plants, as well as by actual analysis, that they are richly imbued with vegetable matter. Nor do the nearly white fire-clays, which in many cases enclose thick courses of the lenticular ore, form any exception to this law; for although, in their present state, they contain little or no carbonaceous matter, the marks of innumerable roots of Stigmaria, and parts of other plants which everywhere penetrate the mass, show that at one time they must have been crowded with vegetable remains.

A further and yet more striking proof of the influence which the contiguous vegetable matter has had in the formation of the proto-carbonate is seen in the fact that the most productive layers of the ore are commonly met with quite near to the beds of coal, and that frequently courses of the nodules are found in the carbonaceous shales or partings which lie in the midst of the seam itself.

While the strata, including the proto-carbonate, are thus distinguished by the admixture of more or less carbonaceous matter, they are *also remarkable for seldom exhibiting a distinctly red tint.* Presenting, where not weathered, various shades of greenish-grey and olive and bluish-black, they only become brown or red where, by exposure to the air, the proto-carbonate has been converted into the sesquioxide of iron. On the other hand, those divisions of the Coal-measures which have been but slightly charged with vegetable matter—as, for example, the Barren shales of the Seral coal-rocks before alluded to—contain much red material both in distinct strata and mottling the general mass, and are throughout more or less impregnated with the sesquioxide.

A like general law as to colour would seem to apply to the other great groups of sedimentary rocks which include, in particular beds, accumulations of vegetable or other organic exuviæ. Thus in the new and old Red-sandstone formations, which generally include so large a proportion of sediment coloured by the red oxide of iron, organic remains are of comparatively rare occurrence, and, when present, are met with almost exclusively in the grey, and olive, and dark-coloured strata which are interpolated in certain parts of the great masses of red material. This relation is beautifully shown in the middle secondary rocks of the Atlantic Slope, which extend in a prolonged belt from the Connecticut Valley into the State of South Carolina. In the strata of red sandstone and shale which form the chief part of the mass, vegetable or animal exuviæ are almost entirely absent; but the remains of fish and impressions of carbonised parts of plants occurring in this group of deposits are found imbedded in layers of greenish and olive sandstones and dark bituminous shales. So in the S. parts of the belt in Virginia and North Carolina, where these rocks include seams of coal and extensive beds of sandstone and shale, containing the remains of plants, the usual red colour is found to give place to the grey, olive, and dark tints of the old Coal-measures, and layers of proto-carbonate of iron show themselves in the vicinity of the coal-seams.

Taken in mass, the red and mottled strata of the unproductive Coal-measures, or of the other groups of red rocks above alluded to, would no doubt be found to contain, in an equal thickness, as large an amount of iron as the coal-bearing strata which include the layers of carbonate—the difference being, that in the former case the metal remains for the most part diffused through the rock as a sesquioxide; while, in the latter, having assumed the condition of proto-carbonate, it has to some extent been concentrated in particular layers or strata. According to a rough estimate of the amount of carbonate ore included in the lower Coal-measures of the Laurel Hill region of Virginia and Pennsylvania, derived from a detailed examination of the ores and associated strata at several points, it may be safely assumed that the equivalent of sesquioxide of iron would not amount to one-third of one per cent of the whole mass of this portion of the Coal-measures, and a proportion not exceeding this is deducible from the measured sections of ore and accompanying rocks in the carboniferous strata of other tracts subjected to a similar calculation.

But even allowing a quantity three times as great as this to cover the diffused carbonate, and the oxide in some cases mingled with it, we should have only about one per cent to represent the proportion of ferruginous matter in the entire mass—an amount undoubtedly much less than what exists in many of the strata of red and purple shales and shaly sandstones of the carboniferous series, or of the groups of red rocks geologically above or beneath it.

In attempting to explain the origin of the proto-carbonate under the conditions above described, it is important to keep in view the fact of the diffusion of this compound through many of the strata as a general constituent, and the frequent preservation even in layers of the ore of the lamination of the contiguous rock. The supposition of its being a chemical deposit formed from springs charged with carbonic acid, and holding proto-carbonate in solution, is evidently inconsistent with these conditions, and not less so with the fact of the great horizontal extension of individual beds of ore and impregnated shaly rocks.

In view of these various considerations it may be concluded—

First, That throughout the Coal-measures and other groups of rocks above mentioned, as well in the portions containing coal and diffused vegetable and animal matter as in the barren parts, the original sediment was more or less charged with sesquioxide of iron; and,

Second, That this sesquioxide in the presence of the changing vegetable matter with which certain of the strata abounded, was converted into proto-carbonate, which remained in part diffused through these beds, or by processes of filtration and segregation was accumulated in particular layers.

It is well known that during the slow chemical changes by which vegetable matter enclosed in moist earth is converted into lignite or coal, both light carburetted hydrogen and carbonic acid are evolved, and that these gases are even eliminated from coal-seams and their adjoining carbonaceous strata. The reducing agency of the carbon and hydrogen, as they separate in their nascent state from the organic matter, is capable, as we know, of converting certain sulphates into sulphurets, and even more readily of transforming the sesquioxide of iron into protoxide. The latter change would doubtless be favoured by the affinity of the carbonic acid present in the mass, for the protoxide thus formed, and in this way the sesquioxide would be entirely converted into the proto-carbonate of iron.

Conceiving a like process to have operated on a large scale in the Coal-measures or other strata containing, when deposited, a mixture of sesquioxide of iron and organic matter, we have a simple explanation of the general conversion of this oxide into carbonate, and of the loss of the reddish colouring in which these materials more or less participated. As these actions must be supposed to have commenced in each stratum as soon as the organic matter contained in it began to suffer chemical change, we may conclude that the formation of the proto-carbonate was already far advanced in the earlier strata when only beginning in those deposited at a later period. Each layer of vegetable matter, as it was transformed into coal, would not fail to impregnate the adjoining beds of shale and sandstone with the proto-carbonate, and thus the development of this compound was, as it were, coeval with that of the coal.

The gathering of the diffused proto-carbonate into bands and courses of ore began, no doubt, as soon as the production of this compound had made some progress; but it probably continued until long after the completion of the chemical changes above described, and indeed it is possible that in some strata it is not yet entirely finished. In this process, which finds a simple explanation *in the combined action of infiltration and the segregating force*, it can hardly be questioned that *the carbonic acid* pervading the mass of sediment acted *a very important part*. The large amount of this gas evolved from the beds of vegetable matter undergoing change would impart to the water of the adjoining strata the power of dissolving the diffused proto-carbonate, which being then carried by infiltration through the more porous beds, would accumulate above and within the close argillaceous or shaly layers, forming in some cases bands of rock ore, in others, courses of nodular and plate ores. Of these, the former would seem to have resulted from the accumulation by *gravity* of the dissolved carbonate in the substance of sandy shales near the upper limit of the more impervious beds, while we may regard the latter as having been collected in all directions from the general charge of proto-carbonate accumulated in the argillaceous mass, its mobility in the dissolved condition greatly aiding the gathering process of the *segregating force*.

The following Table presents, in a condensed view, the chemical constitution of all the chief varieties of the iron ore of the several coal regions:—

ANALYSES OF THE CARBONATES OF IRON OF THE COAL-MEASURES OF PENNSYLVANIA.

Localities, Anthracitic Basins.	Carbonate of Iron.	Peroxide of Iron.	Carbonate of Manganese.	Carbonate of Lime.	Carb. of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Tunnel N. of Gate Vein, Pottsville, . . .	80.85	...	...	1.00	3.86	9.08	2.06	1.02	2.00	39.09	Close-grained, blue, fracture slightly conchoidal.
N. American Mines, Pottsville, ...	39.82	...	a trace	1.00	2.35	50.80	2.80	Sulphur, a trace, Carb. 120	2.00	19.21	Texture coarse, unctuous; spots of iron pyrites.
Below Rabbit-Hole Vein, Pottsville, . . .	63.30	...	a trace	1.50	1.60	25.00	3.20	Carb. 122	1.50	32.6	Lenticular, nodular, blue.
Below a bed of coal at Pottsville, ...	67.80	...	1.00	0.39	a trace	29.00	1.30	...	.50	33.9	Slate-blue, hard, rough.
M'Carty's Tunnel, Pottsville,	26.02	19.36	a trace	0.07	4.04	46.40	2.08	...	1.00	26.39	Slate-blue, slightly unctuous, micaceous.
False Salem Vein, Guinea Hill, Pottsville, . .	56.20	...	a trace	a trace	0.3	39.30	2.80	.50	.20	32.48	Compact, earthy, micaceous.
Guinea Hill, Pottsville, .	63.3	...	...	a trace	1.4	32.0	2.80	...	.40	30.66	Externally in concentric laminæ.
Guinea Hill, 14 inches, Pottsville, ...	67.69	...	...	1.26	2.0	21.0	1.60	1.00	1.40	34.72	Blue, compact, unctuous.
Mann and Williams' Tunnel, Pottsville, ...	72.00	...	a trace	2.08	1.52	21.50	1.60	1.00	3.00	36.00	Blue, slaty, unctuous.
Mann and Williams' Tunnel, Pottsville, . . .	79.20	...	a trace	a trace	a trace	15.0	2.60	Sulphur a trace, Carb. 1.30	1.60	42.8	Blue, earthy, unctuous.
Guinea Hill, another bed, Pottsville, . . .	31.53	31.31	a trace	...	...	31.08	a trace	...	6.06	37.14	Externally concentric, brown; internally hard, blue, meagre; both analysed.
Rabbit-Hole Vein, Pottsville,	48.33	15.06	2.03	3.11	5.11	20.25	1.28	1.81	3.02	33.35	Dull bluish-black, compact.
St Clair Tract, Pottsville, .	42.38	21.32	3.64	...	...	27.63	a trace	...	5.03	34.86	Externally concentric, brown; internally compact; blue, average of all.
St Clair Tract, Pottsville, .	66.67	2.55	a trace	8.25	a trace	13.90	2.25	...	6.10	33.96	Slate-blue, compact.
Mount Laffy, Pottsville, .	39.54	14.57	0.50	a trace	a trace	40.00	...	...	4.60	32.52	Brownish, compact, meagre.
Mount Laffy, another bed, Pottsville, . . .	45.50	...	1.00	6.00	7.50	30.00	2.25	Bi-Sulphuret of Iron, 0.60	7.00	22.05	Blue, compact, crystals of yellow iron pyrites.
Mount Laffy, another bed, Pottsville, . . .	39.54	15.56	0.30	a trace	a trace	39.00	0.50	...	4.50	31.50	Brown, slaty, slightly unctuous.
Zachariah's Run, Pottsville, .	31.07	14.37	1.25	...	2.20	44.80	1.00	...	5.00	25.05	Bluish, slaty, micaceous.
Zachariah's Run, Pottsville, .	35.13	28.10	2.39	0.92	8.79	21.62	0.91	...	1.00	41.88	Dark blue, slaty, and compact, more external brown crust.
Port Carbon, . . .	...	53.56	1.08	...	...	36.01	a trace	...	9.35	37.14	Dull brown, laminated, with clay.
Summit Mine of Lehigh, .	...	37.40	...	a trace	a trace	45.65	18.60	Carb. acid a trace.	4.00	22.98	Slate-blue, compact, nodular, conchoidal, rusty.
Mount Eagle, Black Spring Gap, Dauphin County, .	73.94	10.36	2.95	...	2.07	6.63	...	1.54	1 99	42.22	Nearly black, slaty.
Near Shamokin, ...	56.90	24.90	a trace	a trace	...	16.05	1.00	...	1.50	44.87	Dark blue, compact, and slaty, surface rusty.
Shamokin Mines, another bed, ...	74.50	...	a trace	5.40	a trace	14.30	2.80	...	2.50	35.98	Bluish-black, close-grained, conchoidal.
Shamokin Mines, a third bed,	63.20	...	1.00	...	a trace	31.15	1.50	...	1.50	30.52	Blue-grey, coarse, subcrystalline.
Shamokin Mines, a fourth bed, ...	58.00	8.45	4.50	a trace	a trace	15.44	4.50	Org. Matter 1.50	7.50	45.92	Slate, blue internally; kidney ore, compact, surface rusty.
Shamokin Big Mountain, .	...	79.50	a trace	...	...	4.80	a trace	Org. Matter 2.50	12.50	55.65	Light chestnut-brown, cellular; a surface specimen.
Near Wilkesbarre, . .	37.00	1.20	1.00	1.50	0.50	38.00	3.00	1.50	4.50	30.10	Bluish-grey; externally rusty, slaty.
Lackawanna Valley, . .	39.10	14.05	1.00	2.00	1.00	33.10	2.00	Carb. Matter, 2.00	5.00	32.50	Bluish, conchoidal, unctuous.

TABLE OF ANALYSES OF THE CARBONATES OF IRON—*Continued.*

LOCALITIES, BITUMINOUS DISTRICTS.	Carbonate of Iron.	Peroxide of Iron.	Peroxide of Manganese.	Carb. of Lime.	Carb. of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORE.
Karthaus, Clearfield County (near the conglomerate), .	19.86	34.80	a trace	4.50	...	30.40	1.70	...	8.20	33.95	Mottled-brown, nodular concentric, crust hæmatitic.
Paint Creek, Cambria Co., .	60.90	12.60	...	3.00	...	14.74	2.00	...	6.50	38.22	Buff and slate-blue, sparry, compact.
Near Clearfield Creek, Clearfield County, . . .	50.48	12.79	a trace	0.70	2.43	29.01	...	...	4.59	32.77	Mottled-grey, nodular, sparry.
3 miles S.W. of Clearfield, near the river, . .	56.83	13.21	1.13	...	1.26	24.41	a trace	...	3.16	36.11	Dark blue, rusty, compact, semi-crystalline.
Same as above, another variety, ...	66.37	20.49	2.25	1.07	2.08	6.10	a trace	Sulphur, a trace.	1.64	45.64	Dull blue, compact; drusy cavities, with quartz and pyrites.
Bear Creek Hill, Blossburg, Tioga County, . . .	44.79	8.41	0.88	...	1.99	37.28	0.34	...	6.23	27.05	Mottled-reddish and grey, compact and oolitic.
Blossburg, same bed as above,	...	26.69	0.32	...	0.44	59.36	1.88	...	10.52	18.51	Dingy-brown, internally ochrey in concentric earthy layers.
Warner's, Bennett's Branch, Clearfield County, . .	55.82	...	...	5.0	...	36.80	a trace	...	2.0	26.95	Light grey, oolitic.
Bennett's Branch, above Warner's, ...	73.81	4.24	a trace	a trace	...	14.46	1.00	Org. Matter, 0.50	5.50	38.59	Dull blue, concentric, earthy.
Bennett's Branch, Limestone Vein, ...	55.10	9.50	...	5.80	5.40	18.90	2.10	...	3.00	34.72	Blue-grey; kidney-shaped balls.
Blairsville, Westmoreland County, ...	71.19	...	...	3.50	2.72	17.55	2.10	...	2.70	34.37	Bluish-grey, compact, coarse, and semi-crystalline.
Blairsville, a different variety,	67.20	7.48	...	3.24	1.50	12.34	a trace	...	8.0	37.24	Dove-colour, smooth, nodular.
Lockport (Bog-ore), Westmoreland County, . .	...	77.00	4.50	...	...	4.0	1.50	Org. Matter, 1.22.	12.0	53.90	Brown, ochreous, porous. (Bog-ore.)
Lockport, Westmoreland Co.,	69.0	...	...	7.80	a trace	20.44	a trace	...	2.40	33.32	Dove-colour, nodular, conchoidal, close-grained.
Lockport, Westmoreland Co.,	45.30	...	2.30	32.0	4.50	9.45	1.25	...	6.0	21.86	Slate-blue, compact, slightly conchoidal.
Phipps' Furnace, Scrubgrass, Venango County, . .	96.00	...	a trace	a trace	...	2.10	0.50	a trace	1.0	41.30	Slate-blue, externally brown, compact ball-ore.
Rockland Furnace, Venango County, ...	79.90	...	0.05	2.60	...	14.80	0.50	Org. Matter, a trace.	2.0	38.05	Blue, externally brown, nodular, compact.
Kutcher's, Clarion County, .	76.30	...	0.50	6.0	...	13.30	1.0	...	2.0	59.03	Buhr-stone ore, bluish-grey, compact, conchoidal, spathose.
Kutcher's, another specimen,	87.04	...	...	4.06	...	5.08	0.05	...	1.05	54.14	Dull-red, mottled, soft, and porous, outcrop-ore.
Lucinda Furnace, Clarion County, ...	...	78.22	1.50	...	...	4.80	0.54	...	14.20	54.75	Chestnut-brown, cellular, burnt-stone ore.
Madison Furnace, Clarion County, ...	...	76.1	...	a trace	a trace	7.70	3.60	...	12.50	53.27	Dull-brown, cellular, internally compact, burnt-stone ore.
Porterfield's Furnace, Clarion County, ...	25.30	45.04	1.00	1.78	...	21.50	0.70	...	4.00	35.03	Reddish-brown, oolitic, nodular, concentric crust.
Porterfield's Furnace, Clarion County, ...	...	79.20	1.00	...	...	5.30	a trace	...	14.00	55.44	Brown, slightly cellular.
Deal Bank, 1 mile S. of Shippensville, Clarion County,	...	83.00	2.00	...	...	2.81	a trace	...	12.50	58.10	Purplish-brown, hæmatitic, cellular.
Buffalo Creek, Armstrong County, ...	68.32	...	a trace	15.54	1.35	10.58	a trace	...	4.00	32.95	Internally brownish-blue, externally brown; nodular, compact.
Buffalo Creek, Armstrong County, ...	54.33	...	...	a trace	a trace	40.90	0.50	...	4.00	25.34	More silicious than the foregoing.
BOG ORES:											
Smuller's Furnace, Bog-ore, Venango County, . .	...	80.12	0.50	...	...	3.80	a trace	Org. Matter, 2.00	13.00	56.07	Brownish yellow, soft and pulverulent (bog-ore).
Hickory Furnace, Butler County, ...	...	78.60	0.40	...	...	4.80	a trace	Org. Matter, 2.00	14.00	55.02	Cinnamon-brown, brittle, with plates of hæmatite (bog-ore).

SKETCH OF THE GEOLOGY OF THE UNITED STATES.

To appreciate correctly the geology and mineral resources of Pennsylvania, it is necessary that we should estimate them in their relations to those of the rest of the great area of the middle zone of the continent, of which the State forms but a portion. With a view, therefore, to co-ordinate it with the whole, and with the geology of other quarters of the globe, and for the sake of illustrating local phenomena, which can only be rightly understood through a broad survey of the entire field, I offer to the reader, as an appendix to the foregoing special description of the State, the following general sketch of the Geology of the United States.

The geological formations of the United States comprehend both sedimentary and igneous rocks of all ages, from the earliest gneissic and granitic masses of the primordial crust, to the latest depositions and eruptions of the post-tertiary and existing times. The sequence of formations is, however, not so full as in Europe, there being a few important geological periods not represented by any strata hitherto discovered on the American Continent. This is a fact of much theoretical interest, as it implies that the crust movements were not always coincident in time, nor in the same directions, on the opposite sides of the Atlantic. While the American stratigraphical column is deficient in some members of the great series of deposits found in Europe, it is apparently more full than the European in the subordinate formations composing certain great groups which the two possess in common.

The comparative geology of the two continents will be learned from the following Table, which, omitting any ultimate analysis of the rocks into formations, represents only the great natural groups, or larger series of sedimentary deposits, and gives the co-ordination of these members of the two scales with each other.

Periods represented by European Strata.	American Equivalents.
RECENT	Represented on a grand scale, especially in the alluvial deposits of the present rivers.
QUATERNARY ...	Represented by extensive terrestrial, alluvial, lacustrine, marine, and volcanic deposits.
PLEISTOCENE ...	Represented by terrestrial deposits, with bones of extinct mammalia, by boulder-drift, and the Lawrentian marine clays and sands.
PLIOCENE	Represented by shelly sands on the Atlantic seaboard from Virginia to Texas, and by similar and other marine deposits in California, and by fresh-water deposits in Nebraska.
MIOCENE	Represented by marine beds in New Jersey, Delaware, Maryland, Virginia, and Carolina, and extensively in Oregon and California; also by fresh-water strata in Nebraska.
EOCENE	Represented by extensive marine clays, sands, and limestones, along the seaboard of the Southern States; by wide fresh-water basins in the plains E. of the Rocky Mountains; and by marine deposits in the Pacific slope in California.
CRETACEOUS ...	Diffused extensively from New Jersey to Alabama, and thence Westward to the Rocky Mountains, under the form of sands, clays, marls, and soft grey limestones, layers of gypsum, and beds of the characteristic greensand.
WEALDEN	Probably not represented in North America, though suspected to occur near the Judith River on the Missouri.

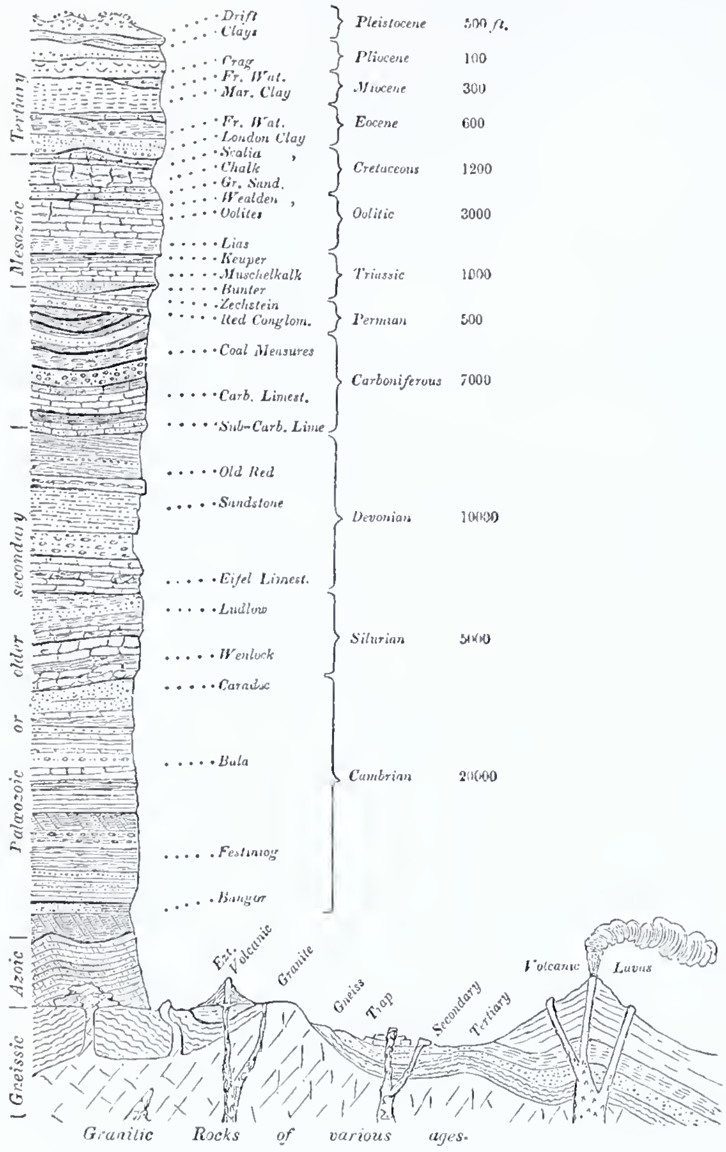


FIG. 584.—Synoptic Diagram of the European Formations.

Periods represented by European Strata.	American Equivalents.
JURASSIC	Represented in Virginia and North Carolina by a group of bituminous coal-measures, and in the valley of the Connecticut and on the Atlantic Slope, from the Hudson River to North Carolina; and again, in Nova Scotia and Prince Edward Island, by belts of a red shale and sandstone formation.
TRIASSIC	Not represented by any formations yet discovered, unless, perhaps, by the above supposed Jurassic red sandstone, &c.
PERMIAN	Supposed to be represented by deposits overlying Coal-measures in Kansas and Illinois, and believed to be in the Black Hills and Guadaloupe Mountains.
CARBONIFEROUS.	Represented very extensively in the United States by Coal-measures and other carboniferous strata, from the Appalachian Mountains to the Missouri River, and within and W. of the Rocky Mountains.
DEVONIAN	Formations of Devonian date occur, widely diffused and under great development, from the Appalachians to the Rocky Mountains, both as respects their thickness and the variety of their organic remains.
SILURIAN	Strata of Silurian age are found extensively distributed in the Appalachians and in the Western States, and likewise in the Rocky Mountains.
CAMBRIAN, OR OLDER SILURIAN.	Strata of Cambrian or Older Silurian age abound in the United States, from the Atlantic Slope to the Rocky Mountains, and probably to the Pacific chain; but, like all the other older Palæozoic series, they are extensively overlaid and concealed by formations of later date.
AZOIC, OR SEMI-METAMORPHIC.	Rocks of the Azoic series, or the Semi-Crystalline strata, next earlier in date to the first fossiliferous formations, abound in the Atlantic Slope, in the Rocky Mountains, and in the Sierra Nevada, and coast-ranges of California.
HYPOZOIC, OR TRUE METAMORPHIC.	The Gneissic or ancient Metamorphic Rocks occur extensively on the Atlantic Slope, especially in New England, also in the Lawrentian water-shed N. of the St Lawrence and Great Lakes, and likewise in the Rocky Mountains, and in the great chain of California and Oregon.
IGNEOUS ROCKS...	The Igneous Rocks of the United States, and the territories adjoining, are recent volcanic eruptions of the volcanoes of Oregon and California and Mexico, and similar volcanic ejections of various tertiary dates; also tertiary and middle secondary basaltic and trappean emissions in great abundance on the Pacific side of the continent; and along the Atlantic Slope, extensive outbursts of trap, of apparently Jurassic age, and there and in the Rocky Mountains numerous dykes and outflows of Plutonic rocks, of all earlier periods, to the most ancient granites and greenstones, contemporaneous with the earliest Hypozoic strata.

Looking at the general features of the Geological Map of the United States, and the territories adjoining, and viewing the more prominent points in the geological structure of this middle portion of North America, we perceive it to consist of five great natural areas: two of them, the largest and most irregular, include nearly all the tracts of the more ancient or Hypozoic and Palæozoic rocks, while the other three contain the chief part of the newer secondary and tertiary, or Mesozoic and Cainozoic deposits. Of the two older areas, the more Eastern embraces all that great division of the United States and the British Provinces which spreads from the Atlantic coast, and S. of New York from the Atlantic plain, W. to the Missouri River, or approximately to the longitude of 97° W., and which, in a N. and S. direction, extends from the termination of the Appalachian Chain in Alabama, and from the Washita River, in Northern Texas, to the Northern limit of the United States, or the territory of Hudson Bay. Throughout this extensive district, which comprises about one-half of the total breadth of the continent in these middle latitudes, there are scarcely any formations of a later geological age than the Upper Coal-measures, if we except certain relatively small strips and patches of Pleistocene tertiary bordering some of the Northern lakes and rivers, and that wide and general superficial covering, the Boulder-Drift, which only partially conceals the more ancient rocky strata, and which is therefore not represented by any special colour on the Map, except in the outline of its lower or Southern border. The other, or more Western region of the ancient rocks, includes the Rocky Mountains and their spurs, the table-land of Northern Mexico, and the whole chain of California, from the peninsula of that name to the Northern and Western ridges of the Sierra Nevada and the Pacific coast range. This area lies approximately between 105° and 123° of W. longitude. It is far less compact than the Eastern or Atlantic region, being much subdivided by numerous and large patches of the Cretaceous strata, stretching round the Rocky Mountains into the desert plateaus W. of them, and by still wider tracts of modern tertiary deposits, covering the vast arid plains and slopes of Oregon, Washington, Utah, and California, from the Wahsatch Mountains to the foot of the Sierra Nevada. This large, irregular, mountainous, and desert tract, includes rocks of all ancient epochs, from the earliest Hypozoic to the Coal-formation inclusive, and abounds in igneous rocks of yet more various ages, from the earliest Plutonic injections to the latest erupted sands and ashes of recently-expired or still living volcanoes.

Of the three areas of the more modern formations, chiefly Cretaceous and Tertiary, the central one, immeasurably the largest, may be defined as spreading from the Southern termination of the Appalachian Hills in Georgia and Alabama, W. to the table-lands of Mexico, N.W. to the E. foot of the Sierra Nevada of California, and the Cascade Chain of Oregon, and N. by the broad plain of the Upper Missouri, to an undefined limit in the N. part of the Continent, in the desert steppes which lie beyond that river, and E. of the Rocky Mountains. The Eastern and central portions of this enormous field of Tertiary and Cretaceous strata, the sediments of a great inland sea, now for the most part a succession of elevated sterile plains and high semi-rainless deserts, is only here and there interrupted by the intrusion of detached patches or island-like masses of the older rocks; but the W. division of the tract, or that between the Rocky Mountains and the Sierra Nevada, is much more cut up and diversified by mountain-spurs and outstanding hills and ridges of the older formations. The scenery of this division of the continent, from the plains E. of the Rocky Mountains to the great Pacific Sierra, being thus composed of extensive horizontal table-lands, deeply gashed by the passage of ancient waters, and of high protruding mountains of every variety of contour, embraces landscapes which are, perhaps, the grandest and most picturesque to be found upon the continent.

The two remaining natural geological areas are the two oceanic belts, chiefly tertiary, which fringe respectively the Atlantic and the Pacific slopes. The Easternmost of these—an extension, properly, of the great central, Newer-Secondary, and Tertiary region—stretches from the S. point of the Appalachians, in a gradually-contracting belt, along the Atlantic seaboard, as far to the N.E.

as Long Island and Martha's Vineyard. It embraces the whole of Florida, and all the lower country of Georgia, of the two Carolinas, and of Eastern Virginia; Maryland, Delaware, and Southern New Jersey. It is nowhere diversified by outbursts of igneous rocks, or the protrusion to the surface of any of the ancient formations, but is characterised throughout by the monotonous features of a low, very level plain, intersected by broad and generally tidal rivers and estuaries, and fringed along a great extent of its sea margin by extensive low swamps.

The other zone of modern or Tertiary strata, that of the narrow Pacific slope of Oregon and California, spreading from the base of the Sierra Nevada and Cascade Mountains to the shore of the Pacific, is much more diversified and interrupted in its physical features than the belt bordering the Atlantic. Consisting of sedimentary formations of geological dates corresponding to that belt, excepting that hitherto no strata of the Cretaceous age have been discovered in it, it has been so severely and frequently invaded by crust movements, and by actual volcanic eruptions, as to have acquired, over a large portion of its length, an excessively rugged surface and diversified structure.

With this general view of the constitution and aspect of the five great geological areas into which, for convenience of description, we have divided the part of the continent occupied by the United States, we shall pass to a more detailed account of the special geology of each division.

HYPOZOIC AND AZOIC METAMORPHIC ROCKS.

Commencing our description with the oldest formations, and observing the ascending chronological order, the first two systems of rocks recognised are those known as the Metamorphic strata. This large class includes, in reality, two, and in some districts, three distinct systems of altered sedimentary rocks, all greatly metamorphosed by igneous action, and plicated and contorted in their bedding, and therefore difficult of stratigraphical analysis. These several metamorphic series are nevertheless distinguishable, when closely investigated, by not merely their differences of crystalline constitution, but by the great horizons of unconformable contact which separate them, amounting to breaks of parallelism both in strike and dip.

GNEISSIC ROCKS.

Description of the Rocks.—The oldest of these systems is that of the true Gneissic or most ancient Hypozoic metamorphic rocks. It consists of the highly-crystallised or true Gneiss in all its varieties—quartzose, felspathic, micaceous, and hornblendic, with fully-developed or typical mica-schist, talc-schist, chlorite-schist, and the other crystalline schists usually classed with the genuine or older Gneiss. Intruded among these strata are numerous veins and dykes of the true igneous or Plutonic rocks of various relative ages, but those which especially characterise this gneissic system are the Granitic and Sienitic rocks, the most ancient of the Plutonic class. Predominant above all the crystalline strata associated with it, is a massive Sienitic gneiss, or thick-bedded gneissoid rock, having in its composition an excess of felspar and quartz. The more micaceous varieties of the true Gneiss of the United States are frequently distinguished by an abundance of the mineral, garnet.

Semi-metamorphic or Azoic Strata.—There probably exist more than one extensive or at least wide break in the succession of strata between the Gneissic series and the overlying

Fossiliferous Palæozoic formations. Indeed, since the early years of the geological surveys of Virginia and Pennsylvania, two such have been partially recognised on the Atlantic Slope in those States, and subsequently the Canadian geological survey has brought to light two horizons of discontinuity, apparently identical with these, insulating a middle metamorphic series of chloritic and epidotic schists, and highly-altered conglomerates, from the Gneissic rocks below them, and from the Palæozoic strata above. This intermediate or Azoic semi-metamorphic system of strata —recognised since 1839, E. of the Blue Ridge in Virginia—consists mainly, along the Atlantic slope of the Southern States, of various coarse talcoid and chloritic schists, semi-porphyritic arenaceous grits and conglomerates, and jaspery and plumbaginous slates, all penetrated extensively by metalliferous veins and dykes, particularly of gold-bearing quartz, and by dykes of porphyritic greenstone, epidote, and other older Plutonic rocks. Nevertheless, it is impossible, in the present early stage of minute field research, to define with any accuracy, over large spaces of country, the upper and the lower limits of this more or less independent semi-metamorphic system ; and it is especially difficult at present to separate it from the overlying genuine Palæozoic formations, into which, indeed, this series may probably graduate in many districts without any physical break at all. The Azoic sediments were succeeded by the Palæozoic, in some quarters apparently with, in some without, the interruption of a disturbance of levels, with undulation amounting to mechanical unconformity. In view of this uncertainty respecting the true limits of the older groups, no attempt is here made to define, in the regions of the Metamorphic rocks, more than two systems—the genuine or older gneissic, and the later or semi-metamorphic strata, the latter including both the supposed middle series, or true Azoic strata, and the proper Palæozoic formations altered in type. This merging of these two latter groups under one series is made indispensable by the absolute impossibility of ascertaining at present the true base of the Palæozoic system, for the history of geology forbids us to believe that research has yet detected the actual horizon of the dawn of animal and vegetable life upon our globe. The tint selected to represent those Azoic and altered older Palæozoic rocks on the Map no doubt covers likewise some tracts of the genuine Hypozoic or Gneissic strata, for nowhere, even along the Atlantic Slope, have all the outcrops of the latter been as yet detected, and accurately mapped. As a general rule, it will be found that the lower or non-fossiliferous Palæozoic formations occupy those parts of the semi-metamorphic belts which lie most contiguous to the zones of genuine fossiliferous strata, while the true Gneissic rocks, involved in the same general plicated tracts, occur on the side most remote from those upper boundaries, namely, for the Atlantic Slope on the E. or S.E. margin of the semi-metamorphic belt.

Along all the Northern border of the Great St Lawrence Basin, there stretches, from the Strait of Belle-Isle almost to the Missouri River, a broad irregular zone of ancient Gneissic and granitic rocks, represented in pale pink upon my Geological Map of the United States. In this imperfectly-explored belt, both in certain districts in New England and elsewhere, the folds or troughs of the Gneiss undoubtedly contain many outlying remnants of semi-metamorphic strata, some pertaining to the Azoic system, some to the Palæozoic ; but no data at present exist for any definition of their local boundaries ; and therefore in this portion of the map, the pink colour must be interpreted as representing all the metamorphic rocks—both those of the true Hypozoic and those of the Palæozoic classes.

Metamorphic Palæozoic Strata.—The metamorphic and semi-metamorphic rocks, which are referable with the least ambiguity to the true Palæozoic system of formations, are the three lowest series or groups of that system, often greatly disguised both as respects their structure and their original composition, by innumerable plications and cleavage-joints, and by a pervading condition of crystallisation of their materials. The lowest group—the Primal series, so called, of the geological surveys of Pennsylvania and Virginia—extending almost the whole length of the Atlantic Slope, from the Blue Ridge of the Southern States to the Green Mountains, and even to Gaspé, has especially been subjected, in all its S.E. outcrops, to thorough metamorphism. But great alteration from igneous action has extended in like manner to the two other series—the Auroral and Matinal groups, constituting with the Primal the older Palæozoic system of the country. Under their more altered type, some of the strata of the oldest or lowest of the Primal slates have the aspect of semi-talcose, chloritic, and micaceous, and even hornblendic schists, with porphyritic, epidotic, and roofing slates; the Primal white sandstone has the aspect in some cases of vitreous quartz rock, in others of a stratified felspar; the impure or earthy magnesian limestones at the passage of the Primal into the Auroral series, has the crystalline structure of coarse granular yellowish and white dolomite and marble, with seams and partings of crystalline scaly talc; and the Auroral blue limestone possesses the aspect and texture of white and mottled crystalline marble, with semi-plumbaginous laminæ; while the grey sandstone of the Matinal series has that of a highly-indurated semi-porphyritic grit, the more argillaceous Matinal shale being in the condition of indurated semi-crystalline clay-slate, partially talcose or nacreous, and intimately pervaded with cleavage. A characteristic feature of all these metamorphic deposits is a close plication or compressed undulation of the strata. This is seen in the steep dips, which agree approximately in their direction over wide belts, and even extensive tracts of country. The alternate foldings of the beds do not take place about axis-planes that are perpendicular, but about planes that incline at angles of 60° or 70° to the horizon. Still farther to confuse the true order of the strata, they are generally pervaded by countless planes of cleavage, which likewise dip with the imaginary axis-planes, or geometric planes, bisecting the anticlinal and synclinal folds. Throughout the Atlantic Slope, in the chain of the Green Mountains of Massachusetts, Vermont, and Canada, this plication observes a remarkable constancy in its direction, the axis-planes dipping, with few exceptions, towards the S.E., or the quarter of the more ancient rocks and chief igneous disturbances and dislocations of the country. These close plications, approaching to parallelism, are only the extreme local exhibition of a great general undulation, with parallel lines of elevation and depression, affecting the entire Atlantic Slope and Appalachian Chain in a stupendous system of waves, which everywhere progressively dilate and flatten down in a N.W. direction.

In the great Pacific Chain this law of close plication has not yet been wrought out in geological sections, but, judging from the universal parallelism of the dip of the strata, and its great steepness, we doubt not that a similar structure will be found to exist in that wide zone of mountains.

Geographical Distribution.—The Metamorphic and Semi-metamorphic strata, thus defined and explained, constitute, it will be observed, two great zones, diverging respectively S.W. and W. from the Gulf of St Lawrence. One is a coast belt, the zone of the Atlantic Slope, extending from Newfoundland through Nova Scotia, New Brunswick, and the New England States, between the waters of the Atlantic and the St Lawrence, and prolonged more inland through New York, New Jersey, Pennsylvania, and the Southern States, to the end of the Appalachian hills in

Georgia and Alabama. It constitutes a large irregular tract between the Atlantic Ocean and the Connecticut River in New England—the hills of Maine and New Hampshire abounding in Plutonic rocks and minerals. The main Gneissic zone terminates at the estuary of the Hudson, but its N.W. axes are prolonged across that river, forming the chain of the Hudson highlands, and, with diminished breadth and elevation, extending to the river Schuylkill in Pennsylvania. From the Delaware River the great Southern zone of Gneiss ranges to Baltimore, Washington, Richmond, Augusta, and onwards, maintaining its position on the S.E. border of the Atlantic Slope to Wetumpka in Alabama. Parallel belts and spurs from this main zone extend, at various intervals, towards the N.W., in the middle of the Atlantic Slope, but throughout the tract the typical Gneiss is subordinate in development to the crystalline schists of equivocal, though probably later age. The other more irregular belt starts from the N. coast of the St Lawrence Gulf, runs S.W. parallel with the river of that name, to the great lakes, and then, deflecting towards the N.W., sweeps the N. shores of Luke Huron and Lake Superior, and reaches the Lake of the Woods, where one great spur of it runs off to the S.W., nearly to the Missouri River, the main zone still holding on N.W., with a gradual Northward inflection towards the Arctic coasts of the continent. The first of these we shall call the Appalachian or Atlantic Metamorphic Belt, while the other may claim the name of the Lawrentian—the Lawrentine Mountains constituting a portion of this zone of uplifted rocks. An extensive tract of Hypozoic and Palæozoic metamorphic rocks occupies the N. part of Wisconsin, and the adjoining part of Michigan between the Mississippi River and Lake Superior. It seems to be a spur from that portion of the Lawrentian gneissic zone which bounds Lake Superior on the N.E.

Standing out somewhat from the metamorphic region of the Atlantic slope of New England, there exists in the N.E. angle of New York, between Lake Champlain and Lake Ontario, a broad rugged district of these older crystalline formations, surrounded on all sides by the most ancient of the fossiliferous Palæozoic strata. The district of the Adirondack Mountains occupies the angle at the forking of the two long primary zones we have been describing, and serves in a measure to unite them. It embraces both hypozoic and greatly-altered palæozoic masses. Other insulated exhibitions of the ancient metamorphic rocks occur to the West of the Mississippi, in three or more detached areas, or local igneous axes ; namely, in the Ozark Mountains in the State of Missouri, in the Washita Hills W. and S. of the Arkansas River, and in Central Texas, on the Rio Colorada, S. of the little river San Saba. Still more detached than the last-named from the main palæozoic region of Eastern America, is that of the Witchita Mountains, which rise N. of the Red River from out of the broad cretaceous plains of Northern Texas.

In the great Primary region of the W. half of the continent, there exist numerous tracts of the metamorphic strata, both Gneissic and altered Palæozoic, with probably others of intermediate age, containing the Granitic and other ancient Plutonic rocks, which so invariably accompany these formations. Long and important outcrops of the true gneissic strata occur throughout nearly the entire range of the Rocky Mountains, including their S. spurs in New Mexico. These rocks especially abound in the main axis of the chain which divides the head-waters of the Missouri from the great Columbia of the Pacific ; also in the Wind River Mountains, a prolongation of the same, and in the Cœur d'Alene, or Bitter Root Mountains, W. of the main axis. They prevail likewise in the Big Horn range near the Yellowstone, and in the central parts of the Black Hills. From the N. fork of the Nebraska, to the sources of the Rio Pecos near Santa Fé, the highest serrated crests of the Rocky Mountains, and the chief axes of nearly all the flanking ridges, exhibit, we believe, the gneissic and granitic rocks in extensive outcrops; and the same is true of the Guadaloupe, Christabelle, and other insulated ridges, which rise out of the cretaceous plains near the Rio del Norte in New Mexico and Texas. To the West of the Rocky Mountains the Gneissic rocks show themselves in some of the higher axes of the great Wahsatch range E. of the Utah Desert, and in several of the ridges of the Humboldt Mountains in the centre of that vast sterile tract. On the W. side of the continent, these ancient strata appear extensively at intervals from the Columbia River to the Californian peninsula, especially at the E. base and in the higher crests of the Sierra Nevada; also in the Coast Mountains, in the San Barnardino Mountains, in the chain of Lower California, in the Colorado Desert, and in the Mexican chain of Sonora. Even in the volcanic chain of the Cascade Mountains of Oregon, and in still more insulated exposures in the volcanic desert of the Columbia River, and in the Tertiary country of the Pacific Slope, these ubiquitous rocks peer to the surface in numerous localities.

Minerals.—In the Gneissic belts magnetic iron-ore and sulphuret of iron abound. Magnetic oxide of iron is found in great veins or dykes in these districts, especially where the typical Gneiss exists in greatest preponderance, and where it has been much convulsed, as in the Adirondack Hills and the outlying spurs W. of Lake Champlain, and in the Hudson highlands, extending from Connecticut across New York and New Jersey to Reading on the Schuylkill. These dykes vary in length from 100 feet to more than a mile. Some have the form of huge flattened oval columns lying obliquely between the strata, but not conforming to their dip. The chief portions of these metalliferous injections actually cut the strata, though for long spaces they may seem to conform to their bedding. The semi-metamorphic Azoic rocks are richer in metallic ores than the early Gneissic. In the Atlantic Slope these ancient crystalline schists contain numerous veins of the ores of lead, copper, zinc, iron, and other metals. They enclose the quartz veins which form the matrix of the gold of California and the S. Atlantic States, and embrace the trappean outbursts, which contain the great masses of copper ore on the borders of Lake Superior, which all appear to have been injected during the deposition of the earlier Palæozoic strata.

PALÆOZOIC FORMATIONS.

The Palæozoic or Ancient Secondary Formations constitute probably one-half of the total area of the United States, and the bordering possessions of Great Britain on the N. They, along with the Hypozoic rocks, underlie, indeed, so large a portion of the whole surface of North America, as to entitle this continent, in comparison with Europe, where they are very subordinate in extent of area to the later Secondary and Tertiary deposits, to be styled geologically the Old World rather than the New. A Palæozoic sea appears to have spread itself from the Hypozoic belt of the Atlantic Slope, across the entire breadth of the present continent, to the Rocky and Californian Mountains, and N.W. over the region of the present basin of the Mackenzie River, even as far as the existing border of the Arctic Ocean. This we may call the Appalachian Palæozoic basin, from the mountain-chain on its S.E. border, in which the sediments of this side of that ancient sea are so extensively and wonderfully exposed. It appears to have been separated from another Palæozoic basin, which occupied all the N.E. tracts of the continent, and had apparently its centre in the great mediterranean sea of Hudson Bay, and its ancient borders in that long semicircular zone of Primary or Hypozoic rocks which sweeps from Labrador, N. of the St Lawrence and the Great Lawrentian lakes, by Lake Winnipeg, Lake Athabasca, and Great Slave Lake, to the Arctic coast between the Coppermine and Great Fish rivers.

The Appalachian Palæozoic deposits of the E. half of the United States are naturally grouped by their organic remains, and the characters of their sediments, into Fifteen distinct series or sets of formations, extending from the deposits which witnessed the very dawn of life upon the globe, to those which saw the close of the long American Palæozoic day, or from the lowest fossiliferous strata to the uppermost beds of the coal series. These fifteen different compound formations. the accumulations of as many successive sedimentary or formative periods, are distinguished by their special physical composition and structure, and by their organic types. In the region of their thickest development, or in the Appalachian Mountains, where the whole system embraces both deep-sea and land-derived or shore-formed accumulations, the total thickness of these slowly-collected sediments, the graves of so many successive generations, is not less than 30,000 or 35,000 feet. The names we have assigned to the fifteen main Palæozoic series —those which have been employed in the geological surveys of Pennsylvania and Virginia—are terms significant of the different natural periods into which the day divides itself, from earliest dawn to latest twilight, and which are metaphorically expressive of the relative dates of production of the several formations. These periods, applicable only to the American Palæozoic day, are the Primal, Auroral, Matinal, Levant, Surgent, Scalent, Pre-Meridian, Meridian, Post-Meridian, Cadent, Vergent, Ponent, Vespertine, Umbral, and Seral,—signifying the periods, respectively, of the Dawn, Daybreak, Morning, Sunrise, Ascending-Day, High-Morning, Forenoon, Noon, Afternoon, Waning-Day, Descending-Day, Sunset, Evening, Dusk, and Nightfall. A nomenclature based on time is, for many reasons, preferable to the inexpressive ones in vogue, which rest on local geographical names, or narrow and inconstant palæontological characters, and is certainly preferable to the geographical nomenclature of the European Palæozoic formations, which, devised for the deposits of a wholly different ancient basin, are inapplicable to the subdivisions of the American strata, with which there is no such strict equivalency or co-ordination as to warrant their having the same appellations.

The three earliest formations, or rather series of strata—the Primal, Auroral, and Matinal—are the near representatives in geological time of the European Palæozoic deposits, from the first-formed fossiliferous beds to the close of the Bala group ; that is to say, they are the proximate representatives of the Cambrian series of Professor Sedgwick. The formations of the next four periods—the Levant, Surgent, Scalent, and Pre-Meridian—are the very near representatives of the true European Silurian deposits, regarding this series as commencing with the May Hill formation—Upper Caradoc sandstone of England—or the horizon which separates the middle from the older Palæozoic divisions. Throughout nearly every explored portion of the Appalachian or American Palæozoic basin (certainly from the Atlantic Slope to the Missouri River—that is, half-way across the continent) there exists both a physical and a palæontological *break* in the succession of the strata at the contact of these two great divisions of the Palæozoic system. This horizon of discontinuity in the ancient deposits, and in the assemblages of the once-living forms which they imbed, is so marked, and so general, as to make it one of the two primary planes by which the whole Palæozoic system of the country arranges itself into three principal divisions. The other horizon is one of somewhat corresponding degree of sharpness, and of wide extension. It is that at the base of the carboniferous strata. Separated by these two breaks or planes of interruption into three large natural divisions, we have the entire Palæozoic system, composed of a Lower Palæozoic division, comprising the three oldest series—the Primal, Auroral, and Matinal—a Middle Palæozoic series, consisting of the rocks of the nine central periods—the Levant, Surgent, Scalent, Pre-Meridian, Meridian, Post-Meridian, Cadent, Vergent, and Ponent —and an Upper Palæozoic division, embracing the true Carboniferous formations of the Vespertine, Umbral, and Seral series, or coal-rocks.

Between the Silurian and the Devonian equivalents there is a much less abrupt plane of separation than the one which divides the Silurian from the Cambrian; that is to say, there exists a greater relative interchange of fossils, and with it, in many districts, a closer blending of the sedimentary deposits than we discern crossing the other platform below. This causes, indeed, some ambiguity in the determination of a proper horizon for provisionally separating the Devonian from the Silurian. Guided by the general *facies* of the fossils—the Mollusca especially—the Meridian or Oriskany sandstone is regarded by some palæontologists, on the original suggestion of M. de Verneuil, as the base of the Appalachian-Devonian deposits; while other naturalists incline to begin the Devonian period at the commencement of the Post-Meridian shales and limestones which overlie or succeed that rock.

The Meridian and Post-Meridian strata—the first a coarse sandstone, characterised by very peculiar brachiopodous shells; the last a blue-and-yellow limestone, marked by distinctive fossils, most of them of Devonian, but some of them of Silurian or Ludlow types—are to be received as representing approximately the older ages of the European Devonian. The next or fourth group of formations in our scale—the uppermost of the Middle Palæozoic—includes the Cadent, Vergent, and Ponent series: the Cadent, a mass many hundred feet in thickness, of dark bituminous shales, with a few calcareous beds; the Vergent, a body of bluish shales and imbedded grey argillaceous sandstones, in some districts more than 3000 feet thick; and the Ponent, a still thicker mass of red shales and argillaceous red sandstones, with a few pebbly beds, having in its greatest development a thickness amounting to even 5000 feet. This group of formations blends in its fossils the characters of the later Devonian and Carboniferous rocks of Europe.

Between this fourth group of the Appalachian formations, or the top of the Middle Palæozoic division, and the succeeding or Carboniferous deposits, it is easy enough to trace the plane of demarcation throughout the Appalachian basin, as far W. at least as the W. disappearance of the older strata under the overlapping cretaceous ones; but this horizon is far more clearly defined physically than palæontologically. A true break in the sequence of actions and in the scale of time—not everywhere marked by actual unconformity or want of parallelism of the dip, but very generally indicated in the discontinuity of the series, such as an omission of one or more of the upper formations of the underlying group—follows the base of the Vespertine, or lower Carboniferous formation, throughout a very large area of the E. half of the continent.

Yet notwithstanding this widely-extended change in the physical geography of the Appalachian sea, affecting the depth of its waters, changing the nature of its sediments, and even shoaling and draining large tracts of its previous bed, the revolution in its marine inhabitants was less complete than that which occurred where the Devonian deposits gave place to Carboniferous ones. Careful and extensive comparisons of the American middle and upper Palæozoic fossils with the European organic relics of the same periods, made by the ablest palæontologists, demonstrate beyond a doubt that, palæontologically, the Carboniferous fauna commences low in the Devonian strata; and we have ourselves established a like early beginning to the typical terrestrial flora, deemed hitherto so characteristic of the true Carboniferous strata. Defined by organic remains alone, the Carboniferous formations of North America exhibit, then, no very clear or recognisable base; and our classification rests mainly on the suddenness of the change from marine to terrestrial forms, and on the rapid coming in for the first time of those remarkable and distinctive physical conditions of the surface, especially that amazing vegetation, and those vast humid plains, by whose agency the characteristic strata of the period, the great coal-seams, were accumulated.

Having thus indicated the general nature of the Appalachian-Palæozoic deposits; our classification and nomenclature of these, the larger subdivisions of the system; and correlated these subdivisions with the great European-Palæozoic series or systems, so called, we present the following synoptic description of these as they exist in the Appalachian Chain, advancing, as on all occasions, from the older to the more modern.

PRIMAL SERIES, OR POTSDAM SANDSTONE OF NEW YORK.

Description.—The Primal series, under its fullest and most diversified condition, or that which it wears in the Appalachian Chain, in Pennsylvania, Virginia, and Tennessee, is a thick fourfold group, composed of two slates and two great arenaceous rocks in alternation—(1.) The highest or Primal newer slate is a greenish and brownish talco-argillaceous slate, sometimes very soft and shaly. In Pennsylvania it has a thickness of about 700 feet. (2.) The next, the Primal white sandstone, is a compact white and yellowish fine-grained vitreous sandstone, often containing specks of kaolin. This rock, which is of easy recognition and of an immense range, has a thickness, in some parts of the Blue ridge of Virginia, of at least 300 feet. This is the Potsdam sandstone of New York. (3.) The Primal older slate is a brown and greenish-grey sandy slate, containing much felspathic and talcose matter. It has hitherto disclosed no fossils. The thickness of this bed, in the Atlantic slope in Pennsylvania, is several hundred feet, and in the Blue Ridge of Virginia is not less than 1200 feet. (4.) The Primal conglomerate, the lowest of the yet distinctly-recognised formations of the Primal series, is a heterogeneous conglomerate of quartzose, felspathic, and slaty pebbles, imbedded in a talco-silicious cement. The thickness of this rock in Virginia and Tennessee, N. of which it has not been discovered, is at the least 150 feet.

In New York and the North-Western States, this series presents a materially different type—the Primal white sandstone being almost the sole representative.

Thickness.—The thickness of the entire series is considerably more than 2000 feet.

Geographical Distribution.—In its geographical distribution, this Primal series ranges coextensively, or nearly so, with the other formations of the older Palæozoic division to be presently traced; that is to say, it shows two great continuous outcrops, one stretching S.W. along the Appalachian Chain, and the other W. from the St Lawrence, through New York, Canada West, Northern Michigan, Wisconsin, and Minnesota, beyond the Mississippi. It is probably likewise brought to the day in the anticlinals of Missouri, Arkansas, and Texas, which elevate the gneissic strata on which it rests. Besides these, its more unequivocal exposures, this group possesses extensive outcrops in various parts of the Atlantic Slope, from the British Provinces on the N.E., S.W. to the State of Georgia. Some of these have been already, as in Pennsylvania, regularly traced and mapped; but for the most part, these Eastern exhibitions of the Primal series are so disguised by metamorphism, so folded, so cleavage cut, and so crystalline, as to be very difficult of geographical delineation. While, therefore, the geologists who have explored the Atlantic Slope are convinced of the presence there of large tracts of the above-described and of still inferior Primal rocks not hitherto brought into the stratigraphical column, their boundaries are not yet sufficiently known to be more than approximately represented on any Geological Map. A considerable portion of the long belts delineated on my Map of the United States as semi-metamorphic slates below the Palæozoic system, both along the Atlantic Appalachian Slope and in the mountain zone of California, consists undoubtedly of these Primal strata disguised by igneous action. The copper-bearing rocks of Lake Superior pertain to this series. The Primal sandstone has lately been discovered in the Black Hills, and doubtless prevails extensively in the Rocky Mountains.

Fossils.—Only the two higher of the above-described Primal strata have yet revealed any fossils: the Upper or newer Primal slate, a peculiar fucoid; and the Primal white sandstone a characteristic stem-like perpendicular form of doubtful affinities, and one or two brachiopodous molluscs, especially a lingula. In Wisconsin and other N.W. localities, this formation contains several species of trilobites, and abounds in lingulæ, obolus, and an orbicula. Trilobites have lately been found in it on Lake Champlain.

Equivalents.—These strata seem to be on the horizon of the lower Festiniog group or *lingula* flags of England, and equivalent to the obolus and lingula sandstone of Sweden and Russia. They represent, too, the primordial zone of Bohemia, and are therefore on the horizon of the very dawn of discovered life.

AURORAL SERIES, or Black River, and Chazy Limestone and Calciferous Sandstone of New York.

Description.—The Auroral limestone, the thickest and most widely extended of all the Appalachian limestones, is a light-blue and bluish-grey compact limestone, usually containing, with the carbonate of lime, from 10 to 30 per cent of the carbonate of magnesia. In many parts of the great Appalachian valley, especially in Virginia, it possesses thick beds of chert. The whole mass has a thickness of not less than 2500 feet in the central part of the Appalachian chain, but it is much thinner in the N.W. States, being at several points not more than 100 feet thick.

The Auroral calciferous sandstone of New York is a coarse grey calcareous sandstone, frequently containing small drusy cavities holding crystals of quartz and of calc-spar. This is a much thinner formation than the main limestone which it supports, being in few places more than 80 or 100 feet thick.

Thickness.—The thickness of the entire series is not less than 2600 feet.

Geographical Distribution.—In its geographical distribution this calcareous group follows closely the Matinal series, with which it is in contact, extending quite as far as it to the S.W., and ranging beyond it in the region of the Upper Mississippi. It is traceable even more continuously from the valley of the St Lawrence by both its great zones of outcrop, which mark respectively the S.E. and the N. shores of the Old Appalachian sea, than the series which overlies it. This latter has in part been washed away from certain synclinal troughs, as that of the St Lawrence, where the deeper Auroral series has been protected and preserved. The formation dipping W. from the Appalachians beneath the great coal-field just reappears in the Ohio and Tennessee great anticlinal, and shows itself again widely in Missouri on some of the uplifts to the W. of the Mississippi.

Fossils and Equivalents.—This great limestone group is less abundant in organic remains than the series which succeeds it, though it has already furnished nearly 100 species, a large proportion of which are restricted to the formation, only five or six being common to it and the Matinal rocks above. Only one or two of these species being identical with any European Palæozoic forms, the group cannot strictly be said to have any European palæontological equivalent. Yet we are entitled, from its place in the system, and from the general facies of the organic remains, to place it upon the horizon of the Festiniog group, or Middle Cambrian of Sedgwick, a part of Murchison's Lower Silurian.

MATINAL SERIES, or Trenton Limestone and Hudson River Slate Group of New York.

Description.—We come now to the uppermost of the three great formations or series constituting the older or lower division of the Appalachian Palæozoic rocks. The Matinal slate formation, or upper division of the series, is a very thick group of argillaceous strata, which have the form of bluish-grey shales, imbedding in their higher portion many strata of argillaceous sandstone, and even some layers of dark-grey silicious conglomerate, and containing in many places, as the lowest member, a dark-blue and even black carbonaceous fissile slate. In some parts of the great Appalachian valley, both in Pennsylvania and Virginia, much red and brown slate alternates with yellow shale in the central and higher parts of the formation. Near the Delaware Water Gap and elsewhere, this middle portion, much metamorphosed and intersected with cleavage-planes, yields a very excellent roofing-slate. In Pennsylvania and Virginia, where this mass appears to be in greatest strength, its maximum total thickness is perhaps 2000 feet.

The Matinal limestone,—the Trenton limestone of New York,—the lower division of the series, is a dark-blue soft argillaceous limestone, containing interposed layers of blue calcareous shale. Many of the limestone bands are excessively fossiliferous. The thickness of this formation in Pennsylvania and New York amounts in some localities to 500 feet, though generally it is less.

These two very distinct divisions of the series maintain their independent types throughout the whole of the Appalachian Chain, where the one appears to have been for countless ages the muddy bottom of a continually-shoaling sea, and the other, which preceded it, the limestone bed of the same ocean, while it was deeper and less invaded by land-derived sediments. In the great anticlinal, which brings the Matinal strata to the day on the Ohio River, they consist of alternating fossiliferous shales and flaggy limestones. This blue-limestone formation of Ohio represents the Matinal slate group.

From Wisconsin W. and S., another limestone formation, the Lead-bearing or Galena limestone of the Mississippi, is intercalated between the Matinal limestone and the Matinal slate of this series.

Thickness.—The maximum thickness of the whole series is upwards of 2500 feet.

Geographical Distribution.—This widespread formation extends the entire length of the Appalachian Chain, from the estuary of the St Lawrence by the valley of Lake Champlain and the Hudson River, and thence by the same Appalachian valley, prolonged through New Jersey, Pennsylvania, Maryland, Virginia, Tennessee, into the interior of Alabama. To the N.W. of this great line of outcrop it reappears in several beautiful anticlinals in the Appalachians of Pennsylvania and Virginia. On the St Lawrence, above Montreal, the main trough of the formation forks, and another outcrop starts off towards the W., ascending the St Lawrence, skirting the

N. shore of Lake Ontario, passing through Georgian Bay of Lake Huron, and the more Northern of the Manitoulin Islands, and sweeping round the N. and W. sides of Lake Michigan, through Green Bay and Winnebago Lake, and thence W. through Wisconsin, until it reaches the Mississippi River. A connecting trough unites the two main zones through the valley of the Mohawk and E. shore of Lake Ontario, so that the gneissic and granitic mountain region of northern New York is entirely encircled by this and the other formations of the older Palæozoic division. Besides these two main outcrops, the series presents itself, in other more local ones, more centrally in the Appalachian basin. It appears in two large patches on the great anticlinal which traverses Middle Ohio, Kentucky, and Tennessee, and shows itself still farther W. on the Missouri, and encircling the anticlinals of the older metamorphic rocks, the Ozark Mountains in Missouri, the Washita Hills in Arkansas, and the San-Saba granitic hills in Central Texas. The Matinal limestone does not everywhere accompany the Matinal shale formation along its great S.E. outcrop; but to the W. of the Appalachian valley it is the more persistent rock of the two, extending into Iowa, beyond the Mississippi, and constituting, indeed, in many parts of the West, the sole representative of the Matinal series. In the large hydrographic basin of Hudson Bay, N. of the Lawrentian Primary or Gneissic zone, this group of older Palæozoic rocks does not reappear, but it shows itself farther W. in the palæozoic basin between Lake Winnipeg and the Rocky Mountains, especially on its E. side.

Fossils.—All the formations of this series are rich in organic remains, some of which are common to the upper and lower strata, but the greater number of the species are restricted to their own deposits. It is remarkable that very few, probably not three per cent, are common to these formations, and to any of the strata which overlie them. The highest organisms hitherto found in these widely-extended rocks are some trilobites, cephalopods, and molluscs; no fishes, nor remains of any vertebrate animals, having ever been detected.

European Equivalents.—The nearest British representatives of these Matinal strata seem clearly to be the Llandeilo and Bala rocks—Lower Silurian of Murchison, or Upper Cambrian group of Sedgwick—the Orthoceratite limestone of Sweden and Russia representing them in Northern Europe.

LEVANT SERIES, OR MEDINA GROUP OF NEW YORK.

Description.—Succeeding the Matinal, and preceding the Surgent in order of time, is another triple formation, here called the Levant series. The upper member of this consists of white and light-grey fine-grained hard sandstone, alternating near its upper limit with beds of red and greenish shale, the sandstone covered with peculiar fucoids in great profusion. This division, in Pennsylvania, measures between 400 and 500 feet. The middle member is a soft argillaceous brown sandstone and red shale. Its greatest development is in the mountains which cross the Juniata River, where its thickness is from 500 to 1000 feet. The third, or lower member, is a hard greenish-grey massive sandstone, embracing in its E. outcrops, as in the Kittatinny and Shawungunk Mountains, thick beds of silicious conglomerate, made up chiefly of the wreck of the previously-formed and disturbed older Palæozoic rocks. This division varies in thickness, in Pennsylvania, from 200 to 700 feet. The uppermost and middle of these is the Medina sandstone of the New York Survey.

Thickness.—The maximum thickness of the whole series is about 2200 feet.

Geographical Distribution.—Tracing them in their geographical distribution, the Levant rocks follow the outcrop of the Surgent series, next to be indicated, W. to Lake Michigan, and S.W., along the Appalachian chain. But in the latter direction, the Levant white sandstone prolongs itself beyond the termination of the Surgent shales, displaying itself in great force in the Clinch Mountain of Tennessee, and other Appalachian ridges, as far as Alabama. The Levant red shale, or middle member, is in full dimensions on the Niagara River, and crosses the peninsula of Canada West. Some of these rocks occur in the Green Mountain chain, and nearer the Atlantic, in the State of Maine, and Province of New Brunswick.

Fossils.—Very few organic remains occur in this group, but those which do are characteristic. The chief marine forms are shells, conspicuous among which is a *lingula*. But more instructive still are the strange fucoids, forms of an ancient marine vegetation, which invariably accompany the upper strata.

European Equivalents.—The Mayhill sandstone, or upper Caradoc, the terminal or lower member of the Wenlock group of England, seems to be on the parallel of this Appalachian Levant series, which is therefore the equivalent of the base of the European Silurian system, if we accept Professor Sedgwick's classification; or the Upper Silurian, if we embrace Murchison's. That it is the base of the American middle palæozoic formations, appears from many considerations, physical and palæontological. The conglomerates mark an ancient shore, and indicate a period of great disturbance and uplift of the earlier Palæozoic strata, accompanied by an almost total change in the organic forms.

SURGENT SERIES, OR CLINTON GROUP OF NEW YORK.

Description.—The next natural group of strata, ascending, the Surgent series of the Pennsylvania Survey, or Clinton group of the New York, is a diversified formation, composed, when fully expanded, of three groups—an upper one, consisting of variegated red marls or calcareous shales; a middle one, of an alternation of shales and argillaceous fossiliferous limestones and calcareous sandstones, with one or two remarkable seams of fossiliferous iron ore; and a lower group, composed of greenish and yellowish fissile slates, weathering olive and claret-coloured, and including in its central part beds of red, very ponderous, ferruginous sandstone, usually containing two or three thin layers, sufficiently rich in the peroxide of iron to be extensively available as an iron ore.

Fossils and Equivalents.—The more calcareous middle member abounds in organic remains, shells, corals, echinoderms, trilobites, &c., all of them of forms significant of an equivalency in age to the Wenlock and other formations at the base of the Upper Silurian series of Europe.

Geographical Distribution.—This series exhibits its maximum thickness and complexity in the central parts of the Appalachian chain in Pennsylvania, gradually diminishing S.W. through Virginia to Eastern Tennessee, where it seems to expire. Traced W., it crosses New York from the neighbourhood of the Helderberg Mountains to the Niagara River; thence sweeps N.W. across Canada West to the Manitoulin Islands of Lake Huron; thence W., by Mackinaw, by the N. shore of Lake Michigan, to Green Bay, and Southward down the Lake Coast in Wisconsin, where it appears to thin out, no part of the formation having been discovered to cross the Mississippi. This N. outcrop, in ranging thus towards the W., displays, what so many of the other formations exhibit, a gradual change from a shore to a mid-sea type, the shales and sandstones becoming progressively less in volume, and the limestone relatively augmenting. A bed of limestone, and another of calcareous shale, are all that represent it on the Niagara River; and in Wisconsin it is composed of little else than a thin stratum of fossiliferous limestone, which is there in contact with the Niagara limestone, with which it has been confounded. It is barely traceable on the borders of the dome-shaped anticlinal of the older palæozoic rocks in S. Ohio and N. Kentucky, and does not appear in that of Middle Tennessee. In the N.E. part of the Atlantic slope and Appalachian chain, the formation presents itself in some outcrops in the Green Mountains, and in the basin S.E. of them in New Brunswick and the State of Maine, but under a less expanded type than that which it assumes in Pennsylvania and New York.

Thickness.—On the Juniata River, in Pennsylvania, the whole series has a thickness approaching 2400 feet, which is probably its maximum in the country.

SCALENT SERIES, or Onondago Salt and Niagara Limestone Groups of New York.

Description.—The series next in order consists strictly of two formations—the upper one a group of gypseous marls and shales, the lower one a compact limestone surmounting grey calcareous shales. The gypseous marls, or Onondago salt group of New York, is a mass of grey or ash-coloured calcareous shale, alternating in its upper part with beds of argillaceous and silicious limestone, some layers of which are curiously pitted with small angular cavities, the nests of solitary crystals of sulphate of lime and carbonate of strontia. Gypsum abounds in this formation, both diffused and in thin seams, and near the surface, in large insulated lenticular masses or cakes.

Geographical Distribution.—The stratum is imperfectly represented in the Appalachian chain S.W. of New York; but it ranges through that State, through Canada West, and through the Western and Northern States almost as far as the Mississippi.

Equivalent.—This formation appears to possess no true equivalent among the rocks of Europe; but as the Scalent limestone below it, and the Pre-Meridian limestone above it, are both on the parallel of the Wenlock group of Great Britain, it is obvious that it belongs to the Wenlock period.

Description.—The other or lower division of the series, the Scalent limestone—the Niagara limestone of New York—is a double formation of limestone and shale, consisting, in its upper division, of a sparry very compact grey limestone, some bands of which are extremely fossiliferous. In its lower portion it is a bluish calcareous shale, somewhat pyritous, and containing a few fossils. The great difference in the susceptibility to erosion of these two strata is the cause of the remarkable terrace and cataract of the Niagara River.

Thickness.—The thickness of the Niagara limestone gradually augments from E. to W.: its maximum is in the region of the Mississippi, being there, it is believed, nearly 1000 feet thick.

Geographical Distribution.—It ranges W. from near the Hudson. The formation traverses the lake peninsula of Canada West, the N. and W. shores of Lake Michigan, the S. part of Wisconsin, and N. part of Illinois, the whole breadth of Iowa, and only disappears where it is overlapped near the Missouri by the Western cretaceous deposits. It rises in the Ohio anticlinal, at the Falls of the Ohio, and appears in Kentucky and Tennessee. It has but little development anywhere in the Appallachian Mountains.

Equivalent.—The Scalent series is on the parallel of the Wenlock formations of Great Britain.

PRE-MERIDIAN SERIES, or Lower Helderberg Limestone of New York.

Description.—The formation which holds the next position in the ascending order is a somewhat diversified limestone formation, consisting usually, in its lower portion, of shales and thin flaggy layers of limestone; in its middle member, of a fossiliferous and sometimes sparry compact grey and blue limestone, containing layers and nodules of chert; and in its upper division, of a dark ash-coloured calcareous sandy shale.

Geographical Distribution.—In the Appalachian chain this rock ranges from near the Hudson S.W. to Tennessee. Its N. outcrop stretches from the same neighbourhood Westward, expiring within 100 miles W. of the River Hudson.

Thickness.—The thickness of the entire formation seldom exceeds 300 feet, and throughout long tracks the rock is very thin.

Fossils and Equivalents.—These marine limestones and shales abound in characteristic organic remains, many of them generically and even specifically identical with the shells, corals, trilobites, and other fossils distinctive of the Wenlock formation of Great Britain, evidently their nearest equivalent in the European system. No remains of fishes, nor vestiges of any vertebrate animal, have ever been discovered either in this formation or in any of the strata beneath it. It may be regarded as the uppermost deposit of the Silurian ages in the Appalachian sea.

MERIDIAN SERIES, OR ORISKANY SANDSTONE OF NEW YORK.

Description.—This is a remarkable arenaceous formation, interposed between the Post-Meridian and Pre-Meridian limestones. The upper member of the series, a rock of rather restricted range in New York and New Jersey, is a calcareous and argillaceous thin-bedded sandstone or grit, characterised in its lower layers by a peculiar fucoid, resembling somewhat a cock's tail. Its thickness, on the Delaware River in New Jersey, is about 300 feet. The sandstone, the principal member—called in the New York Survey the Oriskany sandstone—is a coarse yellowish calcareous sandstone, graduating near its upper limit into a fine-grained quartzose conglomerate, and becoming in its lower beds a coarse arenaceous limestone.

Fossils.—Its distinctive fossils are large brachiopodous bivalves.

Thickness.—The greatest thickness of this sandstone in New York and Pennsylvania is less than 200 feet.

Geographical Distribution.—This formation ranges through the Appalachian chain, is exposed in many outcrops from New York to E. Tennessee, and extends W. from near the Hudson through New York, a distance of about 300 miles. There is no exact equivalent for this stratum among the formations of Europe, though its nearest place in the scale of strata is probably that of the lower Ludlow rocks of England.

POST-MERIDIAN SERIES, OR UPPER HELDERBERG LIMESTONE OF NEW YORK.

Description.—Beneath the Cadent older black slate there lies, throughout the N. States, from near the Hudson, W. through New York, New Jersey, Pennsylvania, Ohio, Upper Canada, Michigan, Indiana, Illinois, Kentucky, Missouri, and Iowa, a widely-expanded marine limestone, the Upper Helderberg, or Corniferous and Onondaga limestone of New York. In Canada and the Western States it is a straw-coloured and light-grey rock, often sparry and sometimes oolitic. It is the upper part of the cliff limestone of the West. In its more Eastern exposures it is generally bluish. It contains nodular chert.

Fossils.—This rock contains many fossils, and some beds of it consist almost entirely of corals and shells, and it is evidently the product of an immensely-extended coral reef. It is the lowest American formation in which there are any remains of fishes: these are large ganoid species, resembling those of the European Devonian rocks.

Thickness.—Its maximum thickness, which is in the Western States, is about 350 feet; but its average depth does not exceed one-third of this.

Equivalents.—The nearest European representative of this rock is the English Ludlow formation; but it contains numerous Devonian fossils, and even some carboniferous ones. It is therefore not exclusively a Silurian equivalent. The occurrence of Productus and Pentramites shows that even carboniferous races tenanted the waters of the Appalachian sea of the Post-Meridian period.

CADENT SERIES, OR GENESSEE, HAMILTON, AND MARCELLUS GROUPS OF NEW YORK.

Description.—This series, like the succeeding one, has its greatest expansion in the Appalachian chain and in Southern New York, and declines steadily in thickness in spreading into the Western States. From New York to Eastern Tennessee it is a group of three formations. The upper or later, the Cadent newer black slate (Genessee slate of New York), is a brownish-black, and in some regions a bluish-black very fissile slate, characterised by numerous small and delicate molluscs, chiefly of Devonian, but some of them of Carboniferous genera, and likewise by remains of a true terrestrial vegetation, generically identical with that of the Coal-measures. This rock has a thickness, in some parts of Pennsylvania, of 300 feet. The middle member or formation, the Cadent shales, the Hamilton group of New York, is a bluish-grey, brownish and olive-coloured clay shale, with thin beds of dark-grey sandstone, sometimes calcareous. It abounds in fossils, especially bivalve shells and corals. Its greatest thickness in Pennsylvania is about 600 feet. The lowest or Cadent older black slate (Marcellus shale of New York) is a black and highly-bituminous slate, graduating upwards into a dark-blue argillaceous shale, surmounted, in some districts, by greenish sandy shales. A thin argillaceous limestone generally occurs near the bottom of the black slate in Pennsylvania, Virginia, and Tennessee. The fossils of the formation are some of them identical with those of the Cadent newer black slate. Many of them are diminutive, and some minute vegetable forms are possibly terrestrial. In Pennsylvania the thickest exposures of this member of the formation measure nearly 300 feet.

Geographical Distribution.—These Cadent strata have their greatest development in the valleys of the Appalachian chain in Pennsylvania and Virginia. Like so many of the other shore-formed deposits of this part of the Appalachian sea, they manifest a gradual reduction of thickness in the S.W. direction, becoming much attenuated before they reach Eastern Tennessee, but, unlike others, one member at least of the series stretches to the W. and N.W. over an enormous distance. The black slate of the Western States shows a continuous outcrop the whole way W. across New York to Lake Erie, and thence S. across Ohio and Kentucky to the anticlinal of Middle Tennessee, which it everywhere fringes. It encompasses, on the E., in like manner, the wide basin of carboniferous strata encircling the Indiana and Illinois coalfield, and, in another belt, crosses the peninsula of Michigan, from the lake of that name to Lake Huron. It seems to thin away by the time it reaches the Kankakee River, on the N. edge of the Illinois coalfield, and in a more Southern latitude in the neighbourhood of the Tennessee River. Rocks of this age are believed to occur in a narrow outcrop bordering the carboniferous basin of New Brunswick.

Fossils.—The Cadent strata are the oldest American formations in which remains of a true terrestrial vegetation have as yet been discovered. Besides these, which are rare, they contain numerous species of mollusca and other marine forms, several of which are identical with European Devonian and Carboniferous species, many being found in no other rock. Goniatites and other carboniferous genera characterise the Cadent black slate both in Pennsylvania and the Western States.

Thickness.—The entire Cadent series is about 1200 feet thick.

These Cadent strata are represented in the Western States, from Southern Ohio both S.W. and N.W., by only one rock, a fissile black slate, which may represent either the upper or lower Cadent formations, but which is generally regarded as the Cadent newer black slate, or Genessee slate of New York. Reposing immediately upon the Postmeridian limestones, and surmounted in turn by the Vergent strata, and W. of the Ohio anticlinal by the Older Carboniferous or Vespertine, and having a very extensive distribution, it constitutes an important stratigraphical horizon. If this black slate be the oldest of the Cadent rocks, the absence of the others establishes an extensive hiatus between it and the Vergent. If, on the other hand, it represents the Cadent newer black slate, a like hiatus exists in the absence of the middle and lower Cadent formations.

Equivalents.—The nearest equivalent of these Cadent strata among the European formations would appear to be the Older Devonian rocks of the Eifel, but, as presently to be intimated of the Vergent, these Cadent strata all contain some carboniferous forms.

VERGENT SERIES, or Chemung and Portage Groups of New York.

Description.—This formation is in two divisions, the upper called, in the New York Survey, the Chemung Group, a thick mass of grey, blue, and olive-coloured shales, and grey and brown sandstones, the sandstones predominating in the upper part, and the shales abounding in fossils, especially Brachiopoda. The lower division, the Portage group of New York consists of a rather fine-grained grey sandstone, in thin layers or flags, parted by thin bands of soft blue shale. Its characteristic fossils are Fucoids, or ancient sea-weeds.

Thickness.—On the Juniata River, in Pennsylvania, the upper rock has a thickness of 3200 feet, while that of the lower amounts to 1700.

Geographical Distribution.—These strata extend South-westward as far as Tennessee, and probably Alabama, and Westward to Ohio, Kentucky, Middle Tennessee, and Missouri. But their equivalents, if they have any farther West in the Appalachian palæozoic basin, have not been ascertained. Vague indications of this series appear in the Rocky Mountains.

Equivalents.—A comparison of their organic remains teaches us that these strata are most nearly represented in Europe by the Eifel strata of the Devonian series. They possess several true Carboniferous species.

PONENT SERIES, or Catskill Group of New York.

Description.—In its fullest development—viz. in Pennsylvania and New York—this is a thick mass of alternating red shales, and red and grey argillaceous sandstones, some of which, in the upper strata, are sparsely sprinkled with white quartz pebbles.

Geographical Distribution.—This rock steadily declines in thickness towards the W., and thins down entirely upon reaching the Alleghany River. South-westward, it extends in several interrupted outcrops along the Appalachian chain as far as Eastern Tennessee, but under a gradually declining thickness. It is absent throughout all the Western States, and even along the Western outcrop of the Appalachian coal-field on the Alleghany River, and South-westward. Nowhere throughout the Western States has any true equivalent or representative of it been discovered; and we are forced to the conclusion, therefore, that a movement of the bed of the Appalachian sea took place at the close of the middle palæozoic periods, preventing a deposition of Ponent strata, and causing here a break in the sedimentary succession, or scale of geological time.

Thickness.—The maximum thickness of the Ponent beds in Eastern Pennsylvania is not less than 5000 feet, and they thin to nothing in a distance of 200 miles.

Fossils and Equivalents.—Few organic remains exist in this formation; but those few, such as the *Holoptychius*, are eminently distinctive of the age of the European Devonian, especially of the Old Red Sandstone of Great Britain. No remains nor footprints of reptiles have ever been discovered in the Ponent strata.

VESPERTINE SERIES, or Lower Carboniferous Strata.

Description.—In its South-eastern outcrops in Pennsylvania and Virginia, this series is a thick mass of white, grey, and yellow sandstones, alternating with coarse silicious conglomerates, and dark-blue and olive-coloured slates. In some localities it includes beds of black carbonaceous slate, and one or more thin beds of coal.

Geographical Distribution.—The Vespertine, or Lower Carboniferous series, has apparently a much less extensive distribution Westward, from its E. outcrops in the Appalachian chain, than the Umbral series which rests upon it. From the district of its maximum development around the anthracite coal-basins of Pennsylvania, we trace it with a rapidly-diminishing bulk duly N.W., until it thins away altogether upon reaching the Alleghany River. Upon the N.W. border of the great Appalachian coal-field it has no existence whatever; but it ranges S.W. from the anthracite country to a far greater distance, following especially the E. margin of the general coal-field, maintaining more nearly its thickness across Virginia and Tennessee. Passing beneath the Cumberland Mountain and its spurs in Alabama, this stratum takes on, like so many others, a less littoral or sandstone type for a more marine or limestone one; and emerging to the day once more in central Kentucky and Tennessee, it begins to assume the characters of a fossiliferous, sandy, and argillaceous limestone. Under this form it underlies the Umbral limestone in Indiana and Western Kentucky, and on the Mississippi and Missouri rivers. In its W. outcrops the stratum is apparently much thinner than the purer limestone group above. How far it spreads to the W. of the Mississippi River has not yet been ascertained. Possibly this formation, and not the Umbral limestone, is the equivalent of the lower Carboniferous group, or gypseous red sandstone of Nova Scotia and Cape Breton. In the absence of more distinctive proofs of equivalency from organic remains, we are entitled to infer that the lower carboniferous strata of the Provinces represent both the Umbral and the Vespertine rocks of the Appalachian basin.

Fossils.—Where it has its E. or ancient shore type, the only organic remains are fragments of coal plants, for the most part specifically different from those of the upper or true Coal-measures. In the Western States it abounds in crinoids and molluscs. To the N.W. of the Appalachian chain, in Northern Pennsylvania and Ohio, this formation grows more argillaceous, and gradually thins away; and on the S.W. outcrop of the great Appalachian coal-field in Kentucky and Tennessee, and in its outcrops circling the great Western coal-fields, the whole mass exhibits a more marine type, its material being chiefly a fossiliferous limestone, filled with oceanic forms, and a grey and yellow sandstone. In the Western States this rock is called the sub-carboniferous limestone.

Thickness.—In Pennsylvania its maximum thickness exceeds 2000 feet.

Equivalents.—This formation belongs to the same period, apparently, as the oldest carboniferous slates of Ireland, or the lowest carboniferous rocks of Europe.

UMBRAL SERIES, OR MIDDLE CARBONIFEROUS STRATA.

Description.—Along the Appalachian chain, this series, in its fullest development, is a triple group, the lowest members consisting of buff, greenish, and red shales, with some sandstone; the middle of a thick mass of light-blue limestone, sometimes oolitic; and the upper of blue, olive, and red calcareous shales, containing massive strata of grey and brownish sandstone. This is the type in Virginia. In Pennsylvania the whole stratum consists of soft red shales and argillaceous red sandstones. In the Western States the principal formations are a light-blue and yellowish limestone, replete in marine organisms, and a grey and yellow sandstone.

Geographical Distribution.—Tracing the Umbral series through its principal outcrops, we find it bordering the several coal-fields of the Eastern British Provinces, under the type of a very diversified group of red shales and sandstones, with conglomerates, calcareous and gypseous marls, and thick beds of limestone, and layers of gypsum; the whole having a maximum thickness of about 6000 feet. Entering the true Appalachian region, we meet the Umbral red shale first in Pennsylvania, and trace it with a gradually declining thickness from its maximum of 3000 feet on the Schuylkill, Southward to the borders of Maryland, where it becomes more calcareous and variegated and fossiliferous, and receives as a middle member the Carboniferous limestone. Advancing in this direction, the limestone gradually augments in thickness, while the upper and lower groups of shale as gradually thin down. But far to the S.W., on the Green Briar River of Virginia, each of the three divisions has a thickness exceeding 1000 feet. The N. outcrop, on the other hand, consisting alone of the red shale and sandstone, grows rapidly thinner as it ranges Westward under the successive anthracite and semi-bituminous coal-basins of Pennsylvania, thinning away entirely at the sources of the W. Branch of the Susquehanna. The Umbral or Carboniferous limestone, if followed as a single formation, first shows its extremely attenuated feathered edge on the Alleghany Mountain, at the sources of the Conemaugh in Pennsylvania. Thence, augmenting Southward, as already said, through Maryland and Pennsylvania, it ranges in great force, though in a narrow outcrop, along the S.E. border of the great coal-field through the latter State, Virginia, Eastern Tennessee, and Northern Alabama, to the termination of the mountains. This rock does not exist at the W. margin of the Appalachian coal-field anywhere in Northern Pennsylvania, or in Ohio; but when we enter Kentucky it gradually developes itself between the Seral and Vespertine strata, and soon becomes a conspicuous formation in the W. escarpment of the Cumberland Mountain, the whole way across Kentucky, Tennessee, and Northern Alabama, expanding widely to the W. in the latter State.

Passing to the other carboniferous districts farther W., this limestone, divided from the broad intervening region, reappears first to the N. in a slender outcrop, encircling the S. half of the coal-field of central Michigan. Leaping a second wide interval, it again shows itself, enclosing the whole of the great coal-field of Illinois, Indiana, and Western Kentucky. There it is comparatively thin at its N. outcrop, but along the E. margin of the coal-field it gradually thickens, and widens its area as it advances S., until, on the Ohio River, and round the S. side of the basin, it acquires a great development. We may next trace it along the S.W. and W. borders of this coal-field, from the Ohio River along both sides of the Mississippi, past the mouth of the Missouri, and skirting the upper Mississippi as far N. as the Red Cedar River of Iowa, near which the anticlinal belt divides, one outcrop turning E. round the Illinois coal-field, the other W. to enclose that of Iowa. From the Mississippi River, between the Ohio and the Missouri, it spreads largely through Southern Missouri, encircling the wide elliptical anticlinal district of the Ozark Mountains, and older Palæozoic rocks at their base. On the W. side of the great W. coal-field of Iowa, Missouri, and Arkansas, this formation once more emerges from under the coal strata, and spreads over a wide belt from their W. border to the E. margin of the unconformably overlying cretaceous deposits of the plains of Nebraska and Kansas. Thickest towards the S., this great marine stratum covers almost continuously the wide district which separates the S. termination of the Appalachian coal-field in North Alabama, from the S. border of the Illinois coal-field in Western Kentucky. Throughout the whole broad area over which we have thus far traced it, we witness a thinning-off in a N.E. direction. While its thickness, on its S. and S.W. outcrops, is in several places from 1000 to 1200 feet, it is no more than 390 feet in Iowa, is much less than this in Northern Illinois, and fines away entirely, in passing under the Michigan coal-field, from its attenuated W. outcrop; and we have seen that in Ohio and Pennsylvania it has no existence.

This widely-diffused formation is not restricted to the E. palæozoic region of the continent, but exists largely developed in the other more insulated ancient tracts of the W. side. It occurs in the Black Hills, in the Rocky Mountains, and in many of the isolated ridges of New Mexico, in which that great chain dies down, and it has been met with extensively in several of the mountain systems still farther W., as in the Wahsatch chain of Utah in the Humboldt Mountains of the Salt Desert, extensively on the Rio Gila, and in the table-lands of Sonora; and it has been detected even in the Sierra Nevada of California. Too little is at present known of the Rocky Mountains and the country W. of them, to permit that detailed separation of the palæozoic system there, which is practicable for the Appalachian basin E. of the central prairies. Recent researches indicate a carboniferous limestone near Fort Laramie, and in the Black Hills; but whether it belongs to the Umbral Series or to the Coal-measures is doubtful.

Thickness.—The maximum thickness of the whole series in Pennsylvania and Virginia is about 3000 feet. In the Western States the limestone exceeds 1000 feet.

Fossils.—Everywhere the fossils are generically identical with those of the great carboniferous limestone of Europe. The Umbral red shale of Pennsylvania contains almost no animal remains, and very few vegetable. It does, however, present, on some of the ancient shore-surfaces, beautifully-distinct footprints of ichthyoid reptiles, and trails of brachiopodous molluscs, and also impressions of a few peculiar aquatic plants. The Umbral limestone, and the variegated shales into which the red shale graduates towards the S.W., abound, on the contrary, in organic remains, corals, crinoideæ, brachiopods, and other molluscs. In Nova Scotia the marine beds contain likewise remains of ganoid fishes.

SERAL SERIES, OR COAL-MEASURES.

Description.—The Coal-measures of the United States and the N.E. British Provinces consist of argillaceous and silicious sandstones and quartzose conglomerates, of clay shales of nearly every colour and texture, of fire-clays and coal-slates, of argillaceous limestones, chiefly of marine origin, and of numerous seams of coal. This coal-bearing group is underlaid throughout nearly all the coal-fields of the country, from Pennsylvania to Alabama and Missouri, by a coarse silicious conglomerate or millstone grit, which also in some localities contains thin seams of poor coal.

Geographical Distribution.—The E. half of the continent contains five great coal-fields, distributed at intervals from Newfoundland to Arkansas. 1. The first, or most Easterly, is that of the E. British provinces—Newfoundland, Nova Scotia, Cape Breton, and New Brunswick—originally a wide coal-field broken into patches by uplifts of the older strata, and by the waters of the St Lawrence Gulf. The surface, covered by the coal-measure of the Provinces, is probably about 9000 square miles; but apparently only one-tenth of this area is productive in coal. 2. The second, which I have called elsewhere the great Appalachian Coal-field, commences in Pennsylvania, and extends S.W. to near Tuscaloosa in Alabama. This includes several outlying lesser basins—those, for example, of anthracite coal in Eastern Pennsylvania. It has a total area of about 70,000 square miles. 3. The third is the smaller coal-field of the centre of Michigan, equidistant from Lake Huron and Lake Michigan. The area of this may be given at about 15,000 square miles. It is very deficient in coal. 4. The fourth is the great coal-field lying between the Ohio and Mississippi anticlinals, and spreading in the form of a wide elliptical flat basin, from Kentucky N. through Indiana and Illinois, to Rock River. This possesses an estimated area of 50,000 square miles. 5. The fifth, and most W., is a long and large coal-field occupying the centre of the great basin of carboniferous rocks, which spreads from the Mississippi and Ozark anticlinals W. to the visible limit of the Palæozoic region, where it is overlapped by the Middle Secondary and Cretaceous deposits of the prairies. The N. limit of this coal-field is in Iowa, on the Iowa River; the S. is near the Red River, on the W. confines of Arkansas; and the total area of the great irregular basin is not less than 57,000 square miles. In a S.W. direction from the S. point of this last coal-field, are three or more small detached patches of coal-bearing strata, surrounded by the superficial cretaceous deposits. These are probably only the denuded outcrops of one long subterranean basin, prolonged from the main one through Western Arkansas and Northern Texas. Besides these chief areas of coal belonging to the E. half of the continent, there would seem to be some localities of this formation bordering the Rocky Mountains, and in the region of the Wahsatch chain of Utah. But so many of the reputed cases of coal discovered in the interior of the continent have proved, upon a geological scrutiny, to be deposits of lignite of the cretaceous and even the tertiary age, that we are cautious, in the present imperfect stage of the evidence, about assigning any of these to the true Carboniferous formation.

Summing up the several areas here defined, we perceive that the broad coal-fields of North America occupy the enormous space of at least 200,000 square miles, or more than twenty times as large a surface as that which includes all the known coal-deposits of Europe, or probably of the E. continent.

Thickness.—Comparative measurements of the thickness of these several deposits of the American Coal-measures, indicate a marked reduction from the E. towards the W. Those of the Nova Scotia field, as measured at the South Joggins, Bay of Fundy, show a thickness of nearly 3000 feet; those of the S.E. anthracite basin of Pennsylvania an average thickness about as great; while the central portion of the great Appalachian bituminous basin has a depth not exceeding 2500 feet. Those, again, of the Illinois basin are probably not thicker than 1500 feet; while the last, the Iowa and Missouri basin, is evidently much shallower, its total depth not surpassing probably 1000 feet.

In Nova Scotia, the coal-fields contain, in the Joggins section, in all about fifty seams of coal, only five of which, however, are of workable dimensions: these are equivalent to about 20 feet of coal. In the deepest anthracite basin of Pennsylvania, that of the Schuylkill, there are, where the formation is thickest, about 50 seams in all; but 25 of these have a diameter exceeding 3 feet, and are available for mining. In the great Appalachian coal-field there appear to be about 20 beds in all, and 9 or 10 of these are of workable size. Again, in the broad basin of Illinois, Indiana, and Kentucky, the total number amounts to 18; and it is believed that 17 of these are of a size and quality suitable for mining. Only 2 or 3 such are believed to exist in the shallow and much-denuded basin of Michigan. Still farther W., the coal-fields of Iowa and Missouri contain, it is believed, only 2 or 3 beds thick enough to be profitable, while the total number of seams of all sizes is probably not more than 12 or 13.

Fossils.—The organic remains of the American coal strata belong to the same forms of vegetation which are typical of the coal-rocks of other countries. Many of the species, however, are local or peculiar. The strata of marine origin contain corals, shells, and remains of fishes; while others formed at the sea-level show the imprints of shore reptiles and molluscs.

European Equivalency.—It is obvious, from the very general accordance between the fossils of the American and the European coal strata, that the former were produced during the age of the upper or main coal-measures of the European carboniferous series.

UPPER COAL-MEASURES; SUPPOSED PERMIAN FORMATION.

West of the Coal-bearing rocks of Iowa, Missouri, and Arkansas, there ranges a belt of overlying deposits through the E. borders of Kansas, from near the mouth of the Platte River to the Canadian, which by some American geologists are regarded as representing the Permian division of the Palæozoic system of Europe. They repose conformably upon the Coal-measures, from which they are not separated by any stratigraphical or physical break. The group consists of a reddish-brown shale, alternating with beds of fossiliferous magnesian limestone. The organic remains, chiefly mollusca, belong in part to species abounding in the Coal-measures beneath, in part to other species here for the first time recognised, which Mr Meek, an able American palæontologist, has discovered to be of Permian genera; but these newly-introduced forms are not specifically identical with their European analogues, and they are sparsely represented, whereas the familiar carboniferous species among which they are dispersed are comparatively very populous. In the absence of any higher organisms decisive of a Permian age and in view of the above facts, showing an intimate relation, physical and palæontological, between these strata and the Coal-measures, it seems inexpedient to give them a separate recognition, such as an independent formation would be entitled to. The deposit may be styled, provisionally at least, the Upper or Newer Carboniferous formation. Its exact age is probably that of the interval or break which separates the European Coal-measures from the Permian deposits which rest unconformably upon them, or it may even overlap the beginning of the Permian period. It was nevertheless essentially a prolongation of the Carboniferous age of North America.

MESOZOIC FORMATIONS, OR MIDDLE SECONDARY STRATA.

Older Mesozoic.—It is remarkable that while the middle latitudes of North America contain very extensive districts of Palæozoic strata, and others almost as wide of the Newer Mesozoic or Cretaceous, and extensive regions of Tertiary or Cainozoic deposits, the Continent embraces an extremely small extent of the Older Mesozoic or Triassic and Jurassic formations. Along the Atlantic Slope these strata exist in narrow detached belts of comparatively restricted length, in situations which indicate that they were accumulated in local estuaries and small basins, and not upon the general oceanic border of the land as it then existed.

Two independent formations or groups of strata of very nearly the same geological age comprise all the older Mesozoic deposits of the Atlantic Slope hitherto ascertained. Possibly the oldest and certainly the most extensive of these is a Red Shale and Sandstone group, distributed in a series of detached basins from Prince Edward Island in the Gulf of St Lawrence to the Atlantic Slope of North Carolina. The other, a Coal formation of very limited area, occurs in three or four small and narrow basins in Eastern Virginia and North Carolina, and South Carolina, immediately W. of the West margin of the Atlantic Tertiary deposits.

Other tracts of Mesozoic strata exist, but farther in the interior of the Continent. One of these, of Jurassic age, occurs in Kansas; another of similar date encircles the Black Hills.

Mesozoic Red Sandstone.—Notwithstanding their insulated position with respect to each other, the several masses of Middle Secondary red sandstone exhibit a remarkable general agreement as regards their composition. Argillaceous red sandstone, red shale sometimes slightly calcareous, grey carbonaceous shales in small amount, and coarse silicious and other conglomerates, are the prevailing sedimentary rocks. Very generally, the whole deposit, especially that belt which extends continuously from the Hudson to the James River in Virginia, consists of three members, the lowest being a conglomerate formed of pebbles of the adjacent older strata, imbedded in a cement of red shale; the middle, an extensive alternation of red shale and argillaceous red sandstone; and the uppermost, often absent, and always of moderate thickness, another conglomerate similar in composition and in origin to the lowest.

That portion of the formation which occupies the S. half of the valley of the Connecticut River consists chiefly of argillaceous sandstone, with beds of red silicious conglomerate, and some partial layers of grey carbonaceous shale, but, on the whole, is much less shaly or argillaceous than the belt which traverses the middle States.

Those patches of the deposit which cover Prince Edward Island and the shores of Cobequid Bay in Nova Scotia, differ chiefly from the others in containing more calcareous cement in the soft red sandstones. The principal strata are coarse red sandstone, coarse heterogeneous conglomerates in the lower part, and soft calcareous red shales.

Geographical Distribution.—Commencing at the N.E., the first tract of Triassic or Jurassic red sandstone is that which skirts the N. shore of Chaleurs Bay in New Brunswick from the neighbourhood of Gaspé Bay S.W.

The next area is Prince Edward Island, almost the whole of which consists of a red sandstone, which some geologists refer to this formation. A third tract is the deposit already referred to as lining the shore of Cobequid Bay, or E. head of Minas Basin in Nova Scotia. This reaches only as far E. as Truro.

In the United States we meet with the next belt in the valley of the Connecticut, where the rock covers an area nearly 155 miles long, by from 7 to 10 miles wide, extending from near the N. line of Massachusetts S. to Long Island Sound.

The largest belt of all, or that of the Middle and Southern States, stretches from the W. bank of the Hudson River, where it is upon the level of the ocean, inland in a S.W. direction along the S.E. side of the South Mountain and Blue Ridge, gradually contracting in breadth, and ascending in level through the States of New Jersey, Pennsylvania, Maryland, and Virginia, to near the centre of the latter, where it terminates.

Another narrow strip of the same rocks runs from a little N. of the Roanoke River S.W. almost to the Yadkin in North Carolina; and between the main belt and this one there occurs a small patch on the James River, in a position which indicates that originally they were all three connected. Some miles to the E. of this principal belt there is another still smaller patch on Willis River, a tributary of the James, which, with one or two other still more trivial outlying masses, implies that there has been an extensive denudation of the original shallow deposit.

The most Southern tract hitherto brought to light lies to the S.E. and S. of the Roanoke belt, and extends from the Tar River, North Carolina, S.W. to a point 8 or 10 miles within the State of South Carolina. This belt passes a few miles to the W. of the city of Raleigh.

Organic Remains and Geological Age.—None of the deposits of the Middle Secondary or Mesozoic red sandstone formation of the Atlantic border abound in fossils, but the vestiges of organic life which they do contain are remarkable. These consist of plants, chiefly terrestrial, of two or three shells, and simple crustaceans, of several fishes, chiefly species of the genus *Catopteris*, of two or three *Thecodontoid Saurians,* and of the footprints of some twelve or fifteen species of quadrupedal animals believed to be reptiles, and of the tracks of between thirty and forty varieties of birds.

The red rocks of Prince Edward Island pertain probably both to the coal period and to that of the other red sandstones farther S., or the earliest Jurassic; some of these strata on the S. side of the island imbed what seem to be carboniferous plants, while others, on the N. side, have yielded a fossil reptile, the *Bathygnathus borealis*, the affinities of which point to a Middle Secondary epoch. No fossils have been discovered as yet in the Nova Scotian Mesozoic basin; but as it evidently lies unconformably in a trough of the carboniferous and other Palæozoic rocks, formed at the close of the coal period, we have the same evidence for its post-carboniferous age which was formerly accepted before the discovery of any fossils in the red sandstone of New Jersey and Pennsylvania, as a sufficient proof of the Middle Secondary date of that deposit. But besides this stratigraphical fact, there are many circumstances of close identity to connect this formation with those of the great Mesozoic estuaries of Connecticut and the Atlantic Slope. Chief among these is a close correspondence in the nature of the sedimentary materials, washings into shallow bays of the soils of the adjacent older rocks; and, secondly, a remarkable analogy in all the phenomena of the trappean rocks which contain native copper and its ores, and which penetrate alike these several formations. These trappean outbursts, closely linked in time with the strata which they penetrate, are so unlike in lithological constitution, in the minerals which they enclose, and in the constant presence of copper, especially in the native state, that we are compelled to regard them as the products of one period—the eruptions, indeed, of one crisis in the disturbances of the Atlantic front of the continent.

The vegetable fossils in the Connecticut sandstone, consisting chiefly of *Cycadites*, *Lycopodites*, a fern, *Clathoptenis meniscoides*, and a few equisetaceæ, display such alliances with those of the Jurassic coal-rocks of Eastern Virginia as to place the early Jurassic or late Triassic age of the deposit beyond a question.

The fossil fishes of the Connecticut Valley, once referred to the genus *Palæoniscus*, but since to a separate genus by Redfield and Sir P. Edgerton, have less heterocercal tails than that Palæozoic family, and plainly indicate a Middle Secondary age. These fossils, occurring both in the Connecticut and the New Jersey deposits, serve to identify these two formations in time, while the occurrence of other species very nearly of the same type in the Liassic coal-rocks of Eastern Virginia supplies a further link to associate these latter with the several different red-sandstone formations which we are describing. Redfield has called one genus Catopteris; the name Ischypterus has been proposed for another by Sir Philip Edgerton. But the most interesting of all the organic remains in the Connecticut red sandstone are the quadruped and biped footprints above referred to. The former, it is believed, were left by different species of lizards, turtles, and frog-like or Batrachian reptiles; the latter by various species of wading-birds, some of them of very colossal size. Coprolites, or specimens of the dung of these creatures, have also been occasionally met with. The tracks occur at intervals throughout a distance of more than 80 miles from Turner's Falls in Massachusetts southward, and are repeated on successive surfaces through a thickness of more than 1000 feet of strata, measuring this by the usual rule of the dip. This, as will presently appear, does not, however, necessarily prove a subsidence of the bed of the red sandstone estuary through so great a space. No actual remains of birds, recognised as such, have hitherto been brought to light; though a few obscure bones, believed to be reptilian, have, it is said, been discovered. As the bird-tracks here spoken of are the earliest vestiges of this high class of creatures yet met with in any country, an especial interest attaches to the determination of the true age of the rocks, of so remote an antiquity, which contain them.

Of the fossils of the Middle Secondary belt of the Middle and Southern States, one of the most significant is a small crustacean form, a *Posidonia* very similar to the *P. minuta* of the European Trias, but believed to be a species of Estherea—not a shell, but a crustacean. This occurs associated with countless multitudes of two minute species of *cypris*, another small crustacean. They are met with abundantly in the thinly-laminated carbonaceous shales of the formation in the interior of Virginia, and as far to the N.E. as the Schuylkill River in Pennsylvania. Being indicative of fresh waters, their presence is expressive of an ancient river flowing into a tidal estuary, debouching where the Hudson now opens towards the sea. Coprolites, probably reptilian, occur with them near the Schuylkill. Still farther to the N.E., but towards the upper or N.W. margin of the formation, near Morristown, and near Pompton, New Jersey, the remains of fishes and a few bird-tracks have been found, identifying, as already stated, this deposit with that of the Connecticut Valley. Besides these, the actual bones and teeth of a saurian reptile (*Clepsisaurus Pennsylvaniensis*) have been recovered from the upper beds of these red sandstones in Lehigh County, Pennsylvania.

In the Eastern Mesozoic belt of North Carolina, conjectured by Professor Emmons to contain deposits of both the Permian and Triassic age, the lower or supposed Permian group has afforded to that observer several thecodont saurians, and an interesting *mammalian* relic, the *Dromatherium Sylvestre* of Emmons. It is supposed, from its dentition, to have belonged to an insectivorous marsupial mammal. As hitherto no mammalian remains have anywhere been met with in deposits older than the Trias, the occurrence of this fossil in the Mesozoic coal strata of North Carolina militates strongly against the hypothesis of their Permian age, and, as Professor Emmons admits, indicates rather an Oolitic or Jurassic date.

Dip of the Red Sandstone, and Physical Conditions attending its Origin.—Some of the features of bedding of the Middle Secondary red sandstones are sufficiently remarkable to claim special mention here. In Prince Edward Island, and in the Nova Scotia basin, the stratigraphical conditions are not peculiar, the rocks in the first-named district being disposed in low and broad undulations, but with a prevailing dip to the N.E., and those in the latter having the form of a regular trough, one side or outcrop reposing with a N.W. dip on the Palæozoic rocks of the S. side of the Bay of Fundy and basin of Minas; the other side with a S.E. dip, skirting the S. base of the Cobequid Mountains, and fringing the N. shore of the same waters. But in the deposit of the Connecticut Valley, and that of the Middle and Southern States, the stratification is decidedly abnormal. Throughout the former there prevails only one direction of the dip, which is a little to the South of East, the average inclination being about 20°, though in some places it is as low as 7° or 10°, and in other places as steep as 40° and 50°. What renders this prevalence of one dip the more remarkable is the absence of any external marks of great faults or dislocations, or of any repetition of the same strata on a section transverse to the strike, the whole formation appearing to be one unbroken sequence of deposits. Over a large part of the tract the beds seem, indeed, to hold the very attitudes or inclinations under which they were formed, though in certain localities, especially towards the W. margin, and adjacent to the larger outbursts of trap-rock, they appear to have been uplifted, or laterally squeezed into steeper inclinations than originally belonged to them.

Throughout the great S. belt, from the Hudson to Virginia, a similar phenomenon of the dip presents itself under circumstances still more striking. Without exception the strata dip in only one direction, but they descend towards the N. and N.W., and not, as in the Connecticut Valley, towards the E. In each instance they dip from one shore towards the opposite, across the entire breadth of the basin or estuary which originally received them. In this longer tract the prevailing slope is 15° or 20°, and it nowhere exceeds about 30°. Everything in the constitution of these strata in both belts—their materials, the direction of their dip, and their oblique bedding—indicate that they were deposited slopingly from one side only of their respective estuaries; and we may see, in the positions of the respective water-sheds which fed them, the features of the physical geography which caused this mode of origin. In the case of the Connecticut estuary, we have merely to suppose that its greatest depth, or its channel, was near its E. shore, and that it was fed by lateral rivers descending E. from the water-shed of metamorphic strata which even now divides the plain of the Connecticut from that of the Hudson River. In the other instance we find, in the existing physical and geological structure of the two borders of this greater estuary, an equally ready explanation of the monoclinal dip and the origin of the materials. The bold features of the mountain-chain which formed the N.W. shore of this great bay and river imply that its deepest channel lay close upon that side; and in the talcose and other metamorphic rocks of the region bordering the estuary on the S.E., which even at this day are remarkable for the red soils they produce, we see the source from whence the materials were derived. The original obliquity of the deposition of the red shales and sandstones is not a matter of hypothesis, but a necessary inference from observed facts of superposition; for in some places, several miles to the N. of the S. border of the belt in Pennsylvania, where—measured by the ordinary trigonometrical rule, which assumes that the strata were originally horizontal, and were afterwards uplifted—the thickness of the deposit should be many thousand feet, we discover it to be actually extremely shallow, denudation having cut entirely through it, and exposed the older system of rocks which constitute its floor.

Interpreting, then, from the facts presented, the physical conditions which attended the beginning, progress, and close of these Middle Secondary deposits, we are entitled to assert that their period was ushered in by a sudden agitation of the region, resulting in an abrupt depression of the tidal portions of each tract below the general ocean-level, or, in other words, in the creation of broad and shallow river-valleys running longitudinally with the mountains, and opening to the sea. Into these newly-created depressions the suddenly-displaced drainage of the bordering tracts would introduce a load of fragmentary matter for the production of those conglomerates which almost everywhere constitute the lower strata of the formation. After the first convulsions were over, a permanent drainage, in the one case from the W., in the other from the S.E. and S., would supply the softer and finer materials of the great body of the deposit. The oblique deposition of these materials would result from their lateral introduction and the scouring action of a strong tidal or river current in the channel, sweeping out all sedimentary matter from the middle and far side of the estuary, and permitting only that to collect which was piled forward, layer upon layer, by muddy tributary streams frequently swollen by rains.

If, in connection with these views of the physical geography of the period, we people the borders of each estuary with the wading-birds and water-frequenting reptiles whose vestiges are impressed upon the once soft strata, and admit the natural assumption that the tracts in which they delighted were the tidal portions of these estuaries, we may readily conceive how the footprints of these animals were buried up and preserved. At each recession of the tide they would go down to feed upon the last newly-deposited silts of the sloping shore, and retiring would leave their footmarks, and then each returning or flood tide, backing the turbid waters descending from the hills, would throw down a fresh layer of sediment to fill these imprints, and preserve them unaltered for an indefinite time.

To account for the very heterogeneous conglomerates which constitute the uppermost or final stratum in so many localities, it is merely necessary to consider what would take place at the first coming on of that series of volcanic actions which produced the great dykes and outflows of trappean lava that occur so extensively in all these Middle Secondary belts. These conglomerates consist almost exclusively of the fragments, imperfectly rounded, of the older rocks of the immediately adjoining hills, imbedded in a paste of the red shaly matter of the waters of the estuary; and it is a significant fact that they include no pebbles of the trappean rocks. The eruption of the trap rocks was therefore posterior to the formation of the conglomerates. Let us, then, suppose that just prior to the actual eruption of the igneous rocks, these Middle Secondary tracts were violently convulsed and partially or even entirely uplifted by vehement earthquakes, and we have at once a sufficient cause for the formation of the conglomerates and the drainage of the basins. The waters of those estuaries containing these terminal breccias must have been lashed violently against the base of the steep bordering hills. In their agitation they would tear off, partially round, and strew the fragmentary materials within their reach, imbedding these in the paste of sand and mud with which they were already charged. The draining-off of the estuary waters towards the side of the ancient channel would naturally produce that oblique dip of the conglomerates under which they seem to have been formed, and by which they abut against the rocks of whose fragments they consist. Further and still more energetic convulsions, with uprising of the land, would complete the desiccation of those tracts which became permanently dry, and result in that extensive rupturing of the crust which gave birth to the dykes and the plateaus of trap-rock that now so extensively intersect these deposits. In certain cases the entire length of each Middle Secondary belt seems not to have been uplifted to the sea-level before the commencement of the trappean eruptions; and those tracts which remained thus submerged are seen to contain, interstratified, as it were, with the later sedimentary deposits, those sandy volcanic tuffs or subaqueous sedimentary forms of trappean matter which constitute the link between the exclusively aqueous and igneous masses. These aqueo-igneous rocks or trap shales abound more in the even now not entirely uplifted basin of Nova Scotia; and they occur to some extent in the lower or more oceanic parts of the other two great estuary tracts—that of the Connecticut River, and that of the Middle States.

Trap-Rocks.—The igneous rocks of these Middle Secondary belts of the Atlantic seaboard constitute one of the remarkable features in the geology of the country. With very few exceptions, they are restricted to the limits of the Red Sandstone deposits, there being obviously some law of connection between their geographical distribution and that of the rocks which they invade. For the most part they occur in great dykes and ridges, ranging longitudinally with the strike of the strata they intersect, or approximately parallel with the borders of the Middle Secondary basin. They are of all dimensions, from ridges and even plateaus many miles in length and several hundred feet in altitude, to short and narrow dykes of the length of a few hundred feet and the width of a few feet or inches. Some of them are approximately straight, but by far the greater number show a curved or crescent shape; and some of them are even hooked at their ends until their points range at right angles to their main portions. With a few exceptions the ends or horns of these crescent-shaped dykes and ridges point in the direction of the dip of the red sandstone strata which they intersect; and this law of their direction is not confined to the great Middle Secondary deposit of the Middle States, but prevails quite as conspicuously in that of the valley of the Connecticut. What makes this the more striking is, that as the strata in these two estuary-deposits dip towards nearly contrary quarters—in the former towards the N.W., in the latter towards the E.—the points of the trappean ridges in the two instances observe corresponding differences of direction. This remarkable relation of the form of the dykes to the dip of the strata enclosing them, has its probable solution in the fact that the trappean matter was extruded partly up the previously established slopes of the obliquely deposited red sandstone, and partly perpendicularly through the transverse breaks in the strata occasioned by the stretching of the crust, and the lifting, as on a hinge, of the outcrop part of the strata borne up by the rising trap.

These rocks consist for the most part of coarsely-crystallised greenstone trap and dykes of more compact basalt. Sometimes the rock is a true dolorite; amygdaloids, or vesicular traps and toadstone, are not unfrequent; and the trap shale or sedimentary aqueo-plutonic variety is also, as already stated, met with.

Of the minerals associated with the trap, the most distinctive are metallic copper and its ores, especially the red oxide of copper, green carbonate, and grey sulphuret; but these do not occur in regular lodes. Specular iron-ore, in small tabular crystals, is also common, and magnetic iron-ore. All these are most apt to occur next the outer walls of the dykes, or in the fissures of the sedimentary rocks immediately contiguous. Many attempts have been made to mine the copper at a profit, but hitherto invariably without success. Other characteristic minerals are—agates, stilbite, laumonite, chabasite, analcime, phrenite, epidote, and occasionally datholite, &c.

Metalliferous Veins.—In two or three dictricts true metalliferous lodes occur within the limits of the middle Secondary red sandstones. And in one locality—that of Montgomery and Chester counties, Pennsylvania—some of these veins have been experimentally mined, and with partial success. These veins are not associated with dykes of trap-rock, but are independent metalliferous injections, consisting of some of the ores of lead, zinc, and copper, involved in various gangue-stones, as quartz, felspar, oxide of iron, &c. The chief ores are sulphuret and phosphate of lead, carbonate and sulphate of copper, and the sulphuret and carbonate of zinc. The Wheatly lode, the most promising of this group, penetrates both the gneissic rocks and the red sandstones. It has already furnished nearly thirty mineral species; among these, some rare crystalline combinations or salts of the metals above named.

Jurassic Coal-Formation.—The Jurassic coal-formation, apparently identical in age, or nearly so, with the Jurassic or Middle Secondary red sandstone, occupies a much more restricted area than that other rock on the Atlantic slope. It is limited, indeed, to a series of small basins strung at intervals along the E. border of the great zone of metamorphic strata, a little West of the Western boundary of the tide-water tertiary plain, from the Potomac to near the Wateree River, in South Carolina. One strip stretches from the W. bank of the Potomac, some miles S. of Washington, in a narrow interrupted outcrop, as far as the James or Powhattan River, obscured for the most part, except where it is intersected by the Chesapeake rivers, by the overlapping lower beds of the Eocene and Miocene tertiaries. This long narrow zone consists chiefly of a soft pebbly imperfectly-cohering rock, a whitish-grey argillaceous sandstone, in which the cementing material of the sand is frequently a white kaolin. Though it contains numerous fragments of an oolitic vegetation, it appears to possess no regular seams of coal. Its position and composition indicate it to have been formed on a line of coast rather than in an estuary.

The next patch, a genuine coal-basin, occurs on a line a little west of the above described, and seems to have been originally more inland. It extends from a few miles N. of the James River to the S. side of the Appamattox River, a length of about 25 miles, with a mean width of 8 or 10 miles, the centre of the trough lying about 12 miles W. of the city of Richmond.

The materials of which this coal-basin consists are principally coarse grey micaceous sandstone, with comparatively little true shale or slate, and they seem to have been derived from the subjacent granitoid gneiss, upon which they immediately repose, in a wide deep trough. These Coal-measures have been penetrated on their E. margin, by mining, to a depth of nearly 900 feet, and a section across the basin shows that they probably have a total thickness in the centre of 1500 or 2000 feet. Only the very lowest portion of the formation is productive in coal: the two, and sometimes three, distinct known seams being all comprised within the lowest, 150 feet. One of these beds, the very lowest, is in some places of enormous size, being as much as 30 feet or even 40 feet thick. It is very variable, however, being in other spots not more than 4 or 5 feet, and appears to have been formed in hollows on an irregular floor of the older rocks, for the bottom of the seam is in some places within a few feet or even inches of gneiss. The coal is a highly bituminous fusible gas-making variety of the species called cherry coal, of a low specific gravity, and a brown streak or powder. The mines are wet and deep, and are not prosecuted with much activity, the total yield of the basin in 1854 being about 150,000 tons.

Fossil Vegetable and Animal Remains.—These coal-bearing strata contain several interesting species of extinct plants, some or all of which have evidently contributed to form the beds of peat out of which the coal-seams were derived; but none of them pertain to the vegetable forms found in the ancient carboniferous strata, or true Coal-measures. Nothing like the old Stigmariæ, Sigillariæ, or Lepidodendra, nor any species of the numerous herbaceous and tree ferns of the older coal have been seen. The distinctive forms are—*Z. tenuistriatus*, *Zamites obtusifolius*, and *Equisetum columnare*, *Lycopodites Williamsonis*, with a noble fern, *Tæniopteris magnifolia*, and *Pecopteris Whitbyensis*. Several of these forms appear to be identical with the well-known fossils of the lower oolitic sandstones of Yorkshire. It is probable that the carbonaceous matter of the coal was largely derived from the fleshy cellular stems of the gigantic Zamias.

Of the animal remains, the most significant relics yet discovered are a few teeth, which seem to have belonged to some saurian, and numerous specimens of two or three genera of very slightly heterocercal fishes, one of which is the *Catopterus Macrurus*. True mollusca are rare; but a shell-like form, the *Posidonia* or *Posidonomia*, once before spoken of, and recently suspected to belong to the crustacean genus *Estheria*, is occasionally found, and is one of the interesting fossil links which connect this oolitic coal-formation with the adjacent Jurassic red sandstones.

Like the red-sandstone basins, this coal-field seems to have been invaded at the date of its elevation by great crust-disturbances, lifting it from the water, faulting its rocks, and injecting it with dykes of trap. Some of these trappean injections appear not to have reached the surface, for they lose themselves between the strata; and in one remarkable case, the igneous rock, traversing or rather resting on one of the coal-seams, has converted it by slow heat and pressure into a natural coke of a dull lustre and great compactness. It is not a true anthracite, but a real coke; and it is doubtful if anthracite on the large scale has ever been produced from bituminous coal through the contact or proximity of igneous rocks merely. The coal-field of Eastern Virginia is excessively fiery, and many disastrous explosions have arisen in the mines from the copiousness of the fire-damp.

The coal-field of Eastern Virginia would appear to have been, at the date of its formation, a fresh-water swamp at the head of a bay penetrating the land from the N., and it is probable that the non-coal-bearing sandstones of the same age in the belts adjoining were deposited on the Western coast of this bay, or the main shore of the continent just outside of it.*

Oolitic Basin, North Carolina.—The third, principal, and by far the largest tract of the Jurassic coal-formation of the Atlantic slope occurs in North Carolina, extending from the Tar River, in a somewhat irregular belt, South-westward, a distance of 150 miles, to Lynche's Creek, or possibly the Wateree River, in the North-eastern corner of South Carolina. Of the geology of this belt less is at present known than of the Virginian belts. The rocks are chiefly argillaceous sandstones; and on the Deep River of North Carolina they contain one or two thin seams of bituminous coal. The principal, and apparently only valuable coal-bed, has nowhere, it is believed, a thickness of more than 4 feet; but it has been detected at intervals along an outcrop of 12 miles, and possibly, therefore, it may one day become of commercial importance. It occurs near the Eastern side of the formation, dipping, with all the rocks yet examined, gently to the Westward; but its opposite dip has never been discovered, and it is not yet ascertained that the strata themselves have the trough-like form, though the occurrence of a continuous seam of coal, which can only have originated when at least its own part of the formation was horizontal, is evidence of a more or less extensive uplifting or basining movement of the crust.

Fossils.—The few organic remains hitherto procured from this Carolina coal-field are in part identical with forms found either in the Virginian Jurassic coal strata, or in the Virginian Middle Secondary red sandstone, of nearly coincident Jurassic date. They are chiefly two or three coal plants, and the characteristic animal remains, *Posidonia* and *Cypris*. With these are the mammalian animal and the Thecodont saurians already mentioned, and remains of fishes.

Besides these Jurassic deposits of the Atlantic slope, there occur other tracts of strata of the oolitic age farther in the interior of the continent. The largest belt there known, outcrops, according to Professor Swallow, the State Geologist of Missouri, between the E. margin of the cretaceous strata and the W. border of the upper carboniferous group, suspected to be Permian, in the E. part of Kansas, running in a slender but expanding zone from a little South of the Nebraska River to the Arkansas River, where the cretaceous formation hides it. But the most satisfactory evidence of the existence of this system of strata in the central tracts of the continent is, according to Dr Hayden, the intrepid explorer of the Neobrara, in the Black Hills of the Rocky Mountains. The formation there constitutes an elliptical zone from 5 to 15 miles broad, encircling the older rocks which enclose the principal axis of elevation of these hills. Dr Hayden states, that " although it is not yet known to occupy a large geographical area, we have indications that it will be found to be extensively developed on the E. slope of the Rocky Mountains;" and he adds, " that he does not doubt that it exists towards the head-waters of the Yellow Stone around Panther and Big Horn mountains." None of the organic remains, it should be mentioned, though the species are numerous, are known to be positively identical with any of the Jurassic fossils of Europe, but so many are closely allied to European Jurassic forms, that Mr Meek and Dr Hayden, who have studied them, do not hesitate to pronounce them of that age.

---

* For fuller details on this subject, consult Reports and Essays of Professor W. B. Rogers.

NEWER MESOZOIC.

Cretaceous Deposits.—One of the most widely-expanded of all the groups of strata in the United States is the cretaceous. Unlike the corresponding series in Europe, it embraces no formation of genuine chalk, though in the S.W. and far West it includes important strata of limestone. Along the Atlantic seaboard, and as far as the Mississippi, the chief materials are beds of sand and sandy clay, with thin layers of argillaceous limestone or calcareous shale; but the arenaceous character generally predominates. A characteristic constituent, especially in the N.E. portion of the Atlantic belt, is green sand or green earth in an arenaceous or granular form—this material existing in thick deposits 20 or 30 feet deep in the lower part of the formation in New Jersey and Delaware. In these States the whole series comprises five separate beds, which, in the ascending order, are:—

I. A group of sands and clays, some of which are extremely pure and white, affording excellent potter's clay.

II. A mixed alternating group of beds of dark-blue sandy clay, with beds of nearly pure greensand, uncemented or arenaceous, which, being endowed with highly fertilising qualities, is ordinarily called the greensand marl.

III. A thin bed, seldom more than a few feet thick, of a porous yellowish or straw-coloured limestone, frequently silicious, and always containing scattered specks of greensand.

IV. A very ferruginous, coarse, yellowish sand, occasionally containing a small amount of a green mineral. This deposit, generally, does not cohere, but near the Rariton Bay some of its layers possess the cohesion of a soft sandstone.

V. A coarse brown ferruginous sandstone, sometimes passing into a conglomerate, forming the fifth and apparently uppermost member of the group. This likewise contains the greensand in minute granules.

The total thickness of the series here described cannot be less than a thousand feet, for it occupies in New Jersey an outcrop several miles in width, with few or no perceptible undulations. Throughout its S. development, in Georgia, Alabama, Mississippi, and Arkansas, the cretaceous series preserves its general arenaceous type, though it is more calcareous than in New Jersey, some of the calcareo-argillaceous beds resembling the European Lias. Advancing W. through Texas and New Mexico, certain members at least of the formation have a more essential marine or deep-sea type, consisting in larger proportion of pure limestones. And this composition would seem to belong to them also farther North, where they spread through the high planes E. of the Rocky Mountains, and lap round the S. spurs of that great chain. Still farther to the N., or along the Missouri and its upper tributaries, where the formation is very widely exposed, the series consists in like manner of limestones, clays, and sands; but it would appear that the latter are relatively more prevalent than farther S. An interesting constituent of the formation is the sulphate of lime or gypsum, which belongs to it more or less throughout its whole wide distribution. It is insignificant in amount in New Jersey and the Atlantic Southern States, but is more abundant in the States north of the Gulf of Mexico. In Texas and in New Mexico this valuable material exists consolidated in beds of great thickness and prodigious expansion, one stratum ranging continuously from the S. tributaries of the Arkansas S.W. to the Rio Picos, and probably to the Rio Grande. Wide beds of gypsum are likewise known W. of the S. spurs of the Rocky Mountains.

Geographical Distribution.—The cretaceous formation would appear to constitute, throughout the middle latitudes of North America, a far wider area than any other group of strata, for it extends continuously from the very shore of the Atlantic in New Jersey, in lat. 41° N., S.W. to Mexico, W. beyond the Rocky Mountains, and N.W. to the sources of the Missouri, covering as much as 40° of longitude, and in the central tracts of the continent more than 30° of latitude. In this amazing geographical distribution, it rivals the great cretaceous deposits of Europe and Northern Africa, compared with which it forms a much more continuous area. Along the seaboard of the Southern Atlantic States it is partially concealed by a superficial covering of the tertiary strata; but from Georgia to New Mexico and the Upper Missouri it spreads in one unbroken tract, suggesting its deposition in a great continental or mediterranean sea. Commencing at the coast in New Jersey, the cretaceous series ranges thence in a contracting belt nearly to the Chesapeake Bay, where, encroached upon by the tertiary, it disappears. But we have indications of its passing under the tertiary plain of Maryland and Virginia, from the frequent occurrence of its characteristic constituent, the greensand, in both the Eocene and Miocene strata of those States. Farther South, the cretaceous formation emerges to the day in a succession of narrow exposures along the seaboard of North and South Carolina, where denuding action, sweeping away the tertiary, has laid it naked in the valleys of all the principal rivers from the Neuse to the great Pedee inclusive. Disappearing again below the tertiary, it emerges a second time in Georgia, on the Savannah and Ogeechee rivers. The great continuous Southern belt commences in Georgia near the Oconee River, south of Milledgeville, and quickly expanding to a width of 60 or 80 miles, extends W. from the Flint River of that State through Alabama, where it sweeps round the S. promontory of the Appalachain chain and the Palæozic formations, and stretches Northward, holding about the same breadth, through Mississippi and Western Tennesse as far as the W. corner of Kentucky. There it crosses the Mississippi, and bending abruptly S. it ranges in a S.W. course, gradually expanding in breadth into the State of Arkansas, where, deflected by the Washita Hills, it once more changes its direction and sweeps W. on the S. side of that axis of older rocks until it enters the broad plains of Texas, where this fringing zone now merges into the broad expanse of the central cretaceous basin of the continent, the wide general limits of which have been already indicated. This central basin, bounded on the E. by the Palæozoic formations of Minnesota, Iowa, Missouri, Arkansas, and Texas, and on the W. by the Rocky Mountains, has the shape and structure of a prodigious valley, between 300 and 400 miles broad, stretching from the Gulf of Mexico N. into the British territory. Between the Arkansas River and the N. line of the United States, its middle tracts are very extensively overspread with tertiary deposits of marine and fresh-water origin, to be presently defined.

According to Messrs Meek and Hayden, the cretaceous deposits of Nebraska are divisible into five groups.

1. A reddish and yellowish friable sandstone, alternating with dark and whitish clays. The organic remains are—layers of impure *lignite*, fossil *wood*, and impressions of *dicotoledonous leaves;* also *Solen*, *Pectunculus*, *Cyprina*, &c. Some doubt exists as to the cretaceous age of this member. Between Council Bluffs and the mouth of the Big Sioux River. Thickness, 100 feet.

2. A dark-grey laminated clay; its fossils are scales and other parts of *fishes*, small *Ammonites*, *Inoeeramus prolematicus* (?) *Serpula*, *Ostrea congesta* (?), &c. &c. Along the Missouri, from near James's River to Big Sioux River. Thickness, 90 feet.

3. A triple group, consisting of a light yellowish-grey limestone below, with *Inoceramus prolematicus*, *Ostrea congesta*, and fish-scales; 30 feet thick; a grey calcareous marl in the middle, weathering yellow, with *fish* remains, and *Ostrea congesta*, 100 feet thick; a dark, smooth, unctuous clay above, containing much carbonaceous matter, with seams of sulphate of lime, and scattered sulphuret of iron, fish-scales, &c. Thickness, 20 feet. These three members are visible in the Bluffs of the Missouri below the Great Bend, and thence to the Big Sioux River.

The 2d and 3d groups are thought to be absent in New Jersey and Alabama.

4. A bluish and dark-grey plastic clay, containing *Nautilus Dekaye*, *Ammonites placenta*, *Baculites ovatus*, *B. compressus*, and many other marine mollusca, and also remains of *Mosasaurus*, occurs along the Missouri River below Fort Pierre; also at Sage and Bear creeks, and at the Great Bend, and near Milk and Muscle Shell rivers. Thickness, 350 feet.

5. Grey and yellow sandy clays and sandstones, containing *Belemnitella bulbosa*, *Nautilus Dekaye*, *Ammonites placenta*, *A. lobatas*, *Scaphites Conradi*, *Baculites ovatus*, and many other marine shells, found at Morean trading-post, and beneath the tertiary at Sage and Bear creeks. In the Fox Hills. Thickness, 130 feet.

Group No. 5, or the uppermost of Nebraska, is believed to represent the Fourth Group, or next to the uppermost of New Jersey; while the main marl-deposit, or next to the lowest group of New Jersey, is the equivalent of the Nebraska Bed No. 4.

Some uncertainty yet prevails respecting the N. limit of the cretaceous rocks in the central plains N. of the Missouri; nor can we trace at present with any precision the W. boundary of the formation where it finally outcrops against the older rocks of Mexico, or is lost to view under the newer tertiaries and volcanic accumulations of the desert plains of Utah and Oregon. The limits assigned show, however, the existing state of information derivable from a careful study of authentic documents and specimens.

Organic Remains and Equivalents.—The fossils of the North American cretaceous deposits pertain to species and genera which represent those of the cretaceous strata of Europe, more especially those which characterise the upper or chalk division of that series. Though the number of species common to the American and European basins is small compared with the whole number discovered, not exceeding probably about 10 per cent, yet 25 or 30 per cent of the known shells of the American group, now amounting to more than one hundred species, are representatives of European upper cretaceous forms; and this may be considered as exhibiting as close an identity in the fauna of that period as prevails between those of the different oceans of the present day.

No mammalian remains have ever hitherto come to light, unless a species referred to the family of Seals, and called *Sternorinchus*, found in the lower greensands of New Jersey, be really a specimen of that high class; but one or two relics of wading birds have been discovered in the greensand marl-pits of New Jersey. The remains of fossil reptilia are much more abundant. One of these belongs to the remarkable saurian genus *Mosasaurus*, others to two or three species of *Teleosaurus*, and as many to crocodiles, and one or two other saurian genera. More than one species of tortoise or Chelonian reptiles have been found. Fossil fishes are also met with, especially of the genera *Carcharodon*, *Lamna*, and *Galeus*. Of upwards of sixty molluscous forms from New Jersey, not more than five or six are actually identical with European species; among these are the *Gryphea eostata*, *Peeten quinquecostatus*, and *Belemnites mucronatus;* but all of them have a great vertical range through the cretaceous rocks of both Europe and America, and are therefore not expressive of very exact equivalency. The thin yellow limestone of New Jersey has furnished several corals, sponges, and other forms which seem to relate it very closely to the upper chalk of Europe, or the limestone beds of Faxoe. More than ten European species have been discovered in the cretaceous strata of Texas out of less than one hundred forms. It is worthy of note that the organic remains from the W. side of the Rocky Mountains agree specifically with those of the cretaceous of the Atlantic States, as suites of specimens from the Rio Puerco, and other localities W. of the Rio del Norte, satisfactorily show.

Lignites and fossil plants, though generally in an obscure and fragmentary condition, are frequently found in the more littoral or lower strata of the cretaceous formation in New Jersey, and the States further S.; and on the Missouri, and especially on the Yellowstone, one of its great Rocky Mountain tributaries, large deposits of lignite have been met with, having the aspect and extended stratification of beds of coal. But it is now perfectly certain that some of these pertain to a lacustrine Tertiary formation, which is known to occur in wide tracts upon the cretaceous strata E. of the Rocky Mountains. As far as the lignites of New Jersey have been examined, they exhibit a vegetation closely agreeing with those of the cretaceous period of Europe.

Physical Geography of the Cretaceous Era.—An examination of the wide cretaceous deposits of the United States indicates a striking difference between the physical geography of this period and that now prevailing. It shows us, as a glance at the Geological Map of the country will prove, that, whatever may have been the area of dry land occupied by the ancient Palæozoic formations in the long interval which elapsed between the first elevation of those strata and the establishment of the boundaries of the cretaceous seas, the boundary or true shore of North America at the beginning of the Cretaceous deposits was that long undulating line which marks the inner or continental margin of the Atlantic and Gulf of Mexico plain, stretching from New Jersey along the foot of the Atlantic slope to the end of the Appalachians, thence N. to the mouth of the Ohio, then S.W. to the Red River, and N. from that to the Upper Missouri. Inside, or N. of this winding shore, lay the smaller North American continent while the cretaceous rocks were forming; and E., S., and W. of it spread the Atlantic Ocean, unbroken by masses of land as far as to where the Rocky Mountains and the chains farther to the W. lifted themselves in the form of a great oceanic archipelago, and to where the great Pacific chain bounded that sea, and either entirely or partially confined it from the ocean to the W. The cessation W. of the cretaceous deposits seems to imply that the now central plain of the continent was in the Cretaceous era occupied by a huge arm of the ocean, or great N. elongation of the present Gulf of Mexico, which washed the base of the western Cordillera, as far towards the North, or farther than the upper waters of the Missouri, just as the Mexican Gulf now washes it in the tropical latitudes. The gigantic scale of the actions which accumulated the cretaceous sediments over this vast inland sea, and those which uplifted it, and drained and denuded its sediments, may be conceived from the simple facts that these deposits possess in the interior of the continent the thickness of nearly one thousand feet, and that vast tracts of them now constitute the great plateaus of the country lifted from 2000 to 6000 feet above the level of the sea.

CAINOZOIC, OR TERTIARY FORMATIONS.

Applying the term Tertiary or Cainozoic to all those deposits which intervene between the Cretaceous series and the accumulations which are now in progress,—deposits entombing the relics of races more or less analogous to the forms which now people the globe, but not identical with them,—I shall proceed to describe the several subdivisions of the series in conformity with the classification which the phenomena require. The American Tertiary strata are separated by nature into four distinct groups, equivalent, approximately, to the Eocene, Miocene, Pliocene, and Pleistocene groups of Europe. These tertiary divisions of the two continents are coordinated with each other, through a sufficient number of identical organic remains, and through such a general analogy in their types, or correspondence in the *facies* of the fossils, as to justify the application, in the absence of a more philosophical nomenclature based on distinctions of time, of the same names to the corresponding divisions of the two series.

The Tertiary deposits of the United States—omitting for the present the latest member of them, or the Boulder-drift and the Pleistocene sediments associated with it—occupy, as will be seen by a glance at the Geological Map, three wide areas, the two oceanic slopes or borders of the continent, and a broad belt E. of the Rocky Mountains.

Atlantic Belt.—The Atlantic or E. belt commences at the N. in the islands of the S. coast of New England and New York. Entering the main land in the E. coast of New Jersey, it stretches thence, in a long zone, of an average width of about 100 miles, constituting the Atlantic tide-water plain, through all the seaboard States to Florida, nearly the whole surface of which it seems to cover. From Florida it ranges W. to the Mississippi, the valley of which it ascends for several hundred miles, beyond which it ranges, again contracting in breadth through Louisiana and S. Texas, until it crosses the Rio del Norte, and, trending S., skirts the W. coast of the Gulf of Mexico. It is a very well defined undulating zone, fringing the present continent in the form of a very level low plain, which scarcely anywhere rises to 100 feet above the level of the sea. This plain has a sandy surface, contains the tidal estuaries of all the Atlantic rivers between the Hudson and those of Mexico, and is intersected with innumerable sluggish creeks, and on its oceanic margin, with a network of low swamps and tidal meadows, particularly through the Southern and Gulf States. Within the territory of the United States alone, the length of this belt, including Florida, exceeds 2400 miles; and if we add the portion in Mexico, its length from Cape Cod to Vera Cruz is not less than 3000 miles. All the four divisions of the tertiary, excepting the drift and its accompaniments, are included in this long zone of marine deposits.

Pacific Slope.—The Pacific slope of the continent, from the Rocky Mountains to the sea, is extensively covered with tertiary deposits of both marine and volcanic origin, the whole being divided into two great zones by the Pacific range of mountains, or the Sierra Nevada and Cascade chains. The broadest and most irregular of these Western tertiary areas covers apparently the entire breadth of the W. desert table-land, including the Utah salt desert, and the volcanic desert of Oregon and Washington; occupying, in other words, nearly the whole space between the Wahsatch and Rocky Mountains on the E., and the Sierra Nevada and Cascade chains on the W., and stretching longitudinally northward a little west, from the Cordilleras of Mexico into British and Russian America. In its S. prolongation, this great tertiary tract declines from its average high level of more than 4000 feet to the sea-level, and even below it, at the Gulf of California; for, N. of that arm of the sea, a portion of the Colorado desert is depressed below the oceanic plain, in one place, to the amount of nearly 300 feet.

The other, or western Pacific belt of Tertiary, fringes the continent in a long and narrow strip, confined between the W. base of the great Pacific mountain-chain and the actual coast. This narrow zone is traceable from the S. end of the peninsula of California, N.W. or N., along the whole border of the continent, as far as Russian America, over a distance quite as great as the Eastern or Atlantic zone. These Western tertiary areas include the same four great divisions of the Cainozoic strata found on the Atlantic side of the continent; and, what is very interesting, they exhibit, in the organic remains, not only the general type or distinctive facies, significant of the period of their formation, but in each case the ordinary proportion of now existing species. This occurrence of the same succession of tertiary formations on the two great ocean-fronts of the continent, is indicative of the amazingly wide areas over which even the later crust-movements of the globe have extended. For there can be but little doubt that the disturbance which changed the Eocene and other waters on the Atlantic side, were contemporaneous with those which altered their sediments and their living races, on the opposite oceanic slope.

Central Tertiary Tracts.—Besides the two grand continuous oceanic areas of tertiary strata, the continent contains, in its more central districts, a number of wide tertiary deposits of more than one epoch. A glance at the Map will indicate the position of several of the more important of these along the W. side of the high plains E. of the Rocky Mountains. These, which for the most part are Miocene fresh-water basins, seem to belong to a great central or continental zone of tertiary deposits, which extends from the Arkansas River across the E. and W. water-shed of the continent, and Northward, in a long and narrow tract, parallel with the Rocky Mountains, to the valley of the Mackenzie River, and by it to the shores of the Arctic Sea. Other more or less insulated deposits of the tertiary strata occur on the opposite or W. side of the Rocky Mountains, between them and the Wahsatch chains. That on the upper waters of the Green River, between the S. pass and Fort Bridger, would appear, like others of the interior basins, to be of Eocene age. There are numerous and very extensive patches of tertiary strata capping the wide cretaceous deposits in Kansas, New Mexico, and Texas, of which we have at present some specific information.

Eocene Formations, Atlantic Slope.—No strata of Eocene age have been discovered in North America, to the E. of the meridian of the Chesapeake Bay, either in the Atlantic coast or in the interior. But from the Potomac River, S. and W., the beds occur in numerous localities, so scattered as to give the impression that the whole of the Atlantic tide-water tertiary plain, as far at least as Texas, is continuously underlaid by the formation. Throughout this zone, wherever Eocene beds appear, they present an extremely gentle inclination towards the Atlantic and Gulf of Mexico, not greater than belongs to the shelving bottom of those waters at the present time, for an equal distance from the coast. Their very slight seaward dip is not the result, therefore, of any uplifting action in the earth's crust, but a consequence of an original trivial obliquity of their planes of stratification; the whole Atlantic front of the continent, and probably the entire continent itself, having been lifted out of the sea at the successive tertiary epochs, either horizontally, or with extremely low crust-undulations.

Tracing the individual outcrops of the Eocene group upon this plain, the first which we encounter, going S., is a long narrow belt, extending from the Potomac, near Washington, across Virginia and North Carolina, to a point beyond the Cape Fear River. Throughout this line those strata lie, in almost horizontal position, against the older upturned gneissic rocks of the Atlantic slope, and in some places in Virginia against the nearly horizontal beds of the Jurassic coal-formation. They are overlaid by a parallel thin deposit of the Miocene tertiary strata, which, on the more upland tracts between the river-valleys, themselves also abut against the older formations, hiding the Eocene from view. The latter are therefore chiefly exposed in the ravines and river sections. All along the line of outcrop, the proper Atlantic slope meets the level Atlantic tertiary plain by an abrupt change in the surface, suggesting an ancient shore; and the line of junction is everywhere marked by a sudden change in the rivers, from the condition of running streams to that of tidal estuaries, each river usually having rapids of considerable extent before it falls into the tertiary plain.

This important physical feature, which prevails, indeed, from the Delaware, at Trenton, to North Carolina, has determined in a striking manner the sites of the principal cities of the whole seaboard of the Middle and Southern States. The upper limit of the tide in the Atlantic rivers being the limit of free navigation, it became the natural place for the transhipment of commodities. This circumstance, and the presence of the water-power of the streams, determined the selection of this boundary for the chief commercial towns in the first settlement of the country; and thus it is that Trenton, Havre de Grace, Philadelphia, Baltimore, Washington, Fredericksburg, Richmond, Petersburgh, Halifax, Raleigh, Colombia, Augusta, Maçon, Columbus, and Montgomery in Alabama, are all seated upon this great natural ancient shore.

Another belt of the Eocene deposits stretches from the Cape Fear River nearly to the Altamaha in Georgia, holding a more central position in the Atlantic plain between the sea and the upper country than the previously described outcrop, and being more interrupted by the overlapping of the newer strata on the water-sheds between the rivers. From the place occupied by this line of exposures, we are entitled to infer something like a very slight arching of the surface at the time of the uplifting and denuding of this part of the Atlantic plain.

Another still larger patch of the Eocene formation extends from near Milledgeville on the Oconee River in Georgia, W. in a narrow belt, across that State, and across Alabama, to the Alabama River, where it commences to expand rapidly, its S. border separating it from the Upper Tertiary formations, ranging nearly W. to the Mississippi at Grand-Gulf, and its N. one turning N., and running through the States of Mississippi and Tennessee, till it meets the Mississippi only a short distance below New Madrid. In the immediate valley of the Mississippi, the W. margin of this broad Eocene tract is formed by the overlapping of the newer alluvium of that mighty river. In Louisiana and Texas there are only two at present distinctly-known patches of the Eocene strata—one on the Nueces River, W. of Nacogdoches, the other on the Rio Brazos, South of Franklin. Nearly all the other portions of the extensive Tertiary plain of these States expose only the Pliocene and Pleistocene beds, and the wide modern alluviums of the existing rivers, though there can be but little doubt that the Eocene underlies the whole. No Eocene strata have hitherto been discovered in the interior of the continent.

We know too little as yet of the Tertiary rocks of the high central table-lands between the Rocky Mountains and the Sierra Nevada to pronounce upon the age of the widespread Tertiary strata which cover them, but certain considerations connected with the physical geography suggest that these desert plains must contain many fresh-water sediments, and make it probable that among them are some of Eocene age. To the W. of the great Californian chain, by far the larger portion of the Tertiary strata occupying the Pacific Slope appears to be of Miocene date; but some genuine Eocene rocks are known to exist there, though covering comparatively very limited tracts. The principal localities of these are in Southern California, N. of the Los Angelos Mountains, or on the verge of the Colorado Desert.

Description of Eocene Strata.—A considerable diversity of composition prevails in the North-American Eocene strata. Those of the Atlantic seaboard, exclusively marine in their origin, are very arenaceous in their more Northern development, but become more calcareous as we trace them S. and W. through the Southern States. In the Virginian outcrop the materials are chiefly argillo-micaceous sands and sandy blue clays, sometimes slightly calcareous and a little gypseous, and frequently possessing a minute quantity of the green granules so characteristic of the cretaceous formation scattered through them. Throughout this belt there is very little limestone.

The middle Atlantic belt, or that exposed upon the rivers of North Carolina, South Carolina, and Georgia, is a much more calcareous formation, consisting of ferruginous and silicious sands, lead-coloured sandy clays, and whitish and bluish friable limestones, with one or more beds of porous chert or burrstone, employed in some localities for millstones. All of these beds are more or less fossiliferous, and some of them excessively so.

The third and next great belt, or that which extends from the Ocmulgee River in Georgia to the Mississippi, may be described as a great triple formation. The upper member consists of two limestone strata, the higher composed largely of that singular foraminiferous fossil, the nummulite, or *Orbitoides*, whence it has been called the nummulitic limestone; and the lower, of a white porous limestone called commonly the rotten limestone, remarkable for containing the bones of a gigantic but slender whale-like creature, the *Zeuglodon cetoides*.

This division considerably exceeds 100 feet in thickness in some localities. The middle member is a ferruginous silicious sand and sandy marl, with a thickness of usually more than 100 feet. It abounds in the well-known Eocene shell, the *Cardita planicosta*, and contains the curious *Ostrea sellieformis*, a fossil which equally characterises the Eocene beds of Georgia and Virginia. The lowest member is a complex limestone and marly deposit of undetermined thickness, but exceeding considerably 100 feet. In this bed occur the above-named and many other shells of characteristic Eocene types. Such is the general aspect of the strata in Alabama and Mississippi.

In Texas the Eocene deposits are likewise both arenaceous and calcareous, the sands being some of them very ferruginous and red. Some of the limestone beds abound in fossils.

Of the Eocene deposits W. of the Rocky Mountains we possess too little information at present to describe their composition with accuracy, further than that some of them contain shales and marls, abounding in lignites and in lacustrine shells and other fresh-water remains.

Fossils and Geological Equivalents.—Throughout the Atlantic seaboard plain—intending this expression to include the Tertiary plain fringing the Gulf of Mexico—the Eocene strata possess certain characteristic fossils, particularly many species of shells which are common to all the districts. Some of these, and a few corals and fishes, are identical with European Eocene forms, while many others are only generically representative of European species. There can be little doubt, therefore, that the Eocene strata of the two continents are co-ordinate in age. Nevertheless, it is not a little remarkable that the two formations are connected by a very small proportion of strictly identical or common organisms. Thus, while more than four hundred species of marine shells, and many echinoderms and remains of fishes, have been procured from the very fossiliferous locality of Clayborne, Alabama, not more than eight or ten of these, or only two or three per cent, prove, upon comparison, to belong to known European types. Notwithstanding, this whole extensive group of organic remains has an unequivocally Eocene facies. Of the remains of fishes the most abundant are the teeth of several genera of sharks —*Carcharodon*, *Otodis*, *Lamna*, and others—belonging to races still higher in the scale. The Atlantic Eocene beds of North America contain several very interesting reptilian forms, among them some species of crocodiles, gavials, and turtles. No terrestrial mammalia, or land quadrupeds, have hitherto been discovered, nor from the marine origin of the beds are such likely to be readily found; but cetacean or oceanic mammalia, as already intimated, do frequently occur, as the zeuglodon of the rotten limestone of Alabama shows. This creature was a kind of slender whale, with yoke-shaped teeth not unlike those of the seal; its vertebræ, as thick as those of the largest whale, were twice as long, and the entire animal had a length, as shown by some specimens, of 70 or 80 feet.

Physical Geography of the Eocene Era.—It is obvious, from the relations of the Eocene and other later Tertiaries to the cretaceous strata upon which they repose, that, however extensively these latter were laid dry at the epoch of the drainage of the great basin in which they were formed, those parts of that basin now overlaid by the Tertiaries must have remained under water, or, if lifted, must have been immediately depressed again to the limit of that great Tertiary shore-line already traced as the inner boundary of the Atlantic plain. Throughout this plain the Eocene strata was quietly deposited in what was evidently a very shallow sea, their materials being derived from the sediments of the rivers descending the Atlantic Slope, and the Great Gulf Slope or S. part of the interior continental table-land. It is worthy of note that opposite the Atlantic Slope and Appalachian Mountains, where so large a proportion of the rocks are of a composition to furnish only sandy and clayey sediments, the Eocene deposits of the Atlantic plain are chiefly arenaceous and argillaceous in their composition, and that farther West, where there is a wide expanse of limestones occupying the great hydrographic basin of the Mississippi and the plains and mountains to the W. of it, the Eocene deposits fringing the Gulf of Mexico are greatly more calcareous and less arenaceous in character. We know at present too little of the geology of the borders of the scattered Eocene basins of the interior of the continent to speculate with profit respecting the physical geography of those regions in that morning of the great Tertiary day, but we may safely conjecture that the draining dry of the great inland Tertiary lakes must have been accompanied by no inconsiderable elevation of the regions bordering the Rocky Mountains, probably by a general bulging of the whole central water-shed of the continent. So long as the zone of country E. of the Rocky Mountains which includes these basins was occupied by the great lakes, the present Missouri River, draining as it does one uniform broad slope towards the E., could have no existence; but there is nothing in the geology of the interior of the continent which forbids the supposition that its present outlines may have been established at the epochs of the movements which terminated the Eocene and the Miocene formations.

MIOCENE STRATA OF THE UNITED STATES.

Geographical Distribution.—The Miocene strata of the United States appear to be far more extensively developed than the Eocene, forming not only the principal Tertiary deposits of the two oceanic belts, but the chief formation of the wide Tertiary plains E. of the Rocky Mountains. Possibly there are strata of this epoch in the broad desert table-lands between the Rocky Mountains and the great Pacific Chain, but none have been hitherto made known on sufficient evidence. In the progress of research it will very probably appear that wide tracts of the Atlantic plain in the Southern States, including Texas, are underlaid by Miocene strata exposed at intervals in the river-valleys; and the same remark may be applied to the Eocene. In like manner, it is very probable that Miocene strata occur at intervals along both coasts of the peninsula of Lower California.

Miocene on the Atlantic.—Restricting our attention, in the first place, to the well-ascertained Miocene areas of the Atlantic border, we find that they are all embraced in that part of the tide-water plain which extends from Martha's Vineyard, on the coast of New England, to the neighbourhood of the Cape Fear River in North Carolina, and in other detached patches farther South, as far as Georgia. Martha's Vineyard consists almost entirely of this formation, and Long Island appears to be, in part at least, underlaid by it. The principal area, however, is on the mainland, where it appears first in two or three very shallow patches on the E. and S. coasts of New Jersey, and then in a wide continuous sheet, covering nearly the whole breadth of the Atlantic plain from the Delaware Bay to the Neuse River, abutting on its W. margin against the older metamorphic rocks, at the base of the Atlantic Slope, and fringed on its E. by a thin capping of Pliocene deposits, stretching from the Chesapeake Bay to Pamlico Sound. Over all this tract the Miocene beds are abundantly exposed in the banks of the rivers and creeks, where they are now becoming extensively sought for, their calcareous shell-marls being applicable to the purposes of agriculture.

Description.—The Atlantic Miocene deposits consist, for the most part, of yellow and brown ferruginous sands, sandy blue clays, and calcareous clays and sands, imbedding extensive layers of uncemented fossil-shells, and other extinct organisms. As a mass, the formation contains fewer cemented beds than the Eocene of the more southern States, not having any true limestones or silicious burrstones. It resembles more closely, in general composition, the underlying Eocene of its own district, even in possessing a certain proportion of the green-sand characteristic of the cretaceous group which underlies them both.

Pacific Belt.—Though we are much less accurately acquainted at present with the distribution of the Miocene strata on the Pacific slope of the continent, we are enabled, by assembling the observations of different explorers, to represent at least one great belt as covering a large portion of the long narrow seaboard belt which intervenes between the W. base of the Sierra Nevada and Cascade Mountain, and the coast. It is believed that the chief part of the Tertiaries of this diversified zone belong to the Miocene period, but it is very probable that future researches will disclose not only Eocene, but Pliocene and Pleistocene deposits also. As already intimated, this margin of the continent differs essentially from the Atlantic Tertiary plain in its physical features, which are those of a broken and hilly tract sloping rather steeply towards the sea, traversed transversely by rushing rivers, undulated by chains of ridges and even mountains, and in some quarters dotted with volcanic hills. As might be expected from such a topography, the Tertiary beds are seldom in a horizontal position, but are uptilted and dislocated, and disposed in great undulations, the axes of the waves conforming in their directions to the general trend of the coast and the older mountains. The Coast Mountains, so called, and the Monte Diavolo range, consist largely of the Miocene strata, thus undulating. These seem to repose, in many places, immediately upon the crystalline stratified rocks; in other localities they rest directly upon ancient Tertiary trachytes, and other effusions of extinct volcanoes.

Description of the Strata.—As we might anticipate, from the more disturbed and volcanic character of the immediate Pacific Slope, as compared with the Atlantic plain, the Tertiary strata of California and Oregon are in a greatly more indurated or rocky condition than those of the E. coast. They consist largely of sandstones, conglomerates, and shales, with occasional beds of chert, but very rarely of limestone. Some of the sandstones are fossiliferous, the organic remains which they contain being sufficiently well preserved to establish their Miocene age. Extensive beds of infusorial earth belong to one portion of these upper Tertiary strata, and occur at intervals for more than 400 miles along the coast belt. A very interesting bed of infusorial earth, consisting chiefly of various forms of fossil Diatomaceæ and Desmidiæ, occurs near the base of the Miocene formation, above its contact with the Eocene, in the State of Virginia. This has been traced, at intervals, from the Potomac to the Meherrin rivers, on the S. borders of Virginia, a distance of more than 150 miles. In some places its thickness is from 20 to 30 feet, and it is made up almost exclusively of the silicious cases of these microscopic organisms.

Miocene Strata of the Central and Western Parts of the Continent.—In several places E. of the Rocky Mountains, broad patches of Miocene deposits cover the cretaceous strata in the high half-sterile steppes of the great interior plains. How far S. these shallow Tertiary basins extend we are at present unable to say; but there are some of them in Kansas, and probably even in Northern Texas, as we know there are to the W. of the Rocky Mountains, in New Mexico and Utah; but going N. we encounter a larger basin on the upper waters of the Nebraska or Platte River, extending from E. of Fort Kearney to Fort Laramie, or almost 300 miles. This vast Tertiary basin spreads S. nearly to the Arkansas River, and N.W. beyond the South Fork of the Shayenne, or nearly to the foot of the Black Hills, occupying the country of the Niobrara and White Earth rivers. It contains the celebrated *Mauvaises Terres*, or Bad Lands, a desert region of arid table-lands gashed into innumerable ravines insulating vertical precipices, and detached, flat-topped, turreted columns, the whole cut by deep denudation into an extraordinary labyrinth, 30 or 40 miles in diameter. In the Bad Lands the deposits are exclusively of fresh-water origin, as will be shown presently in speaking of their organic remains. The lignites and leaves of deciduous and coniferous trees, and some few molluscous fossils, all go to prove that at least some of these strata were accumulated in fresh-water lakes. Indeed, on both sides of the Rocky Mountains we have proofs of physical conditions in the early Tertiary times not unlike those which prevailed in the Eocene ages in France and other Tertiary countries of Europe, where lakes and estuaries entombed the remains of terrestrial and fresh-water animals and plants; and volcanic disturbances shortly afterwards arose to uplift and alter or entirely drain them.

Fossils and Equivalents of the Miocene.—The Miocene tertiaries of the Atlantic plain consist of about two hundred well-ascertained species, comprising corals, molluscs, certain crustaceans, several fishes, chiefly of the shark tribe, a few reptiles, and one or two cetaceans or marine mammalia. Of the shells and corals not more than twenty per cent can be recognised as belonging to races now alive; nor is it probable that future researches will materially modify this proportion. Very few of the extinct species are common to the strata of America and Europe, and out of one hundred and forty-seven of the American fossils, including both extinct and recent forms, reviewed by Sir Charles Lyell, only thirteen were found to be likewise European. Several of the most abundant of these Miocene remains are recent species now restricted to the Western or American side of the Atlantic. The Miocene shark's teeth appear, some of them, identical with those of the middle tertiary strata of Touraine. The nearest European equivalents of the Atlantic Miocene beds would seem to be the English crag and the faluns of Touraine.

Nebraska Basin.—The fresh-water Miocene strata of the Bad Lands of the Niobrara and White rivers abound in admirably well-preserved remains of an extraordinary extinct fauna. Professor Leidy of Philadelphia, who has described them, has shown that they contain three species of OREODON, a genus of ruminant quadrupeds intermediate between the existing ruminants and the fossil ANOPLOTHERIUM; two species of AGRIOCHŒRUS, ungulated ruminants of the same intermediate type; one species of POEBROTHERIUM, a ruminant allied to the living musks; three species of LEPTAUCHENIA, and one of PROTOMERYX, also ruminants. Of *Multungula*, or many-toed quadrupeds, he has detected, in the remains brought in by Dr Hayden and others, eight species belonging to the genera CHŒROPOTAMUS, ENTELODON, TITANOTHERIUM, PALÆOCHÆRUS, LEPTOCHÆRUS, and RHINOCEROS; besides three species of ANCHITHERIUM, a solidungulate genus, allied to the living horse and the extinct *Palæotherium;* also five genera of RODENTIA, among them a porcupine; together with seven species of CARNIVORA, consisting of *Hyænodon*, three species; *Amphicyon*, two—*Deinictis* and *Machairodus*. In addition to these, there occur an interesting Chelonian reptile, the *Testudo Nebracensis*, and four fresh-water shells, one land-shell, and a small fresh-water crustacean, the *Cypris Leidyi*.

Another extensive basin of Miocene age, known as the Great Lignite Basin, extends on both sides of the Missouri River, from about longitude 103° W. to the valley of the Yellow Stone, which descends to the mouth of the Big Horn. Outlying patches of this area occur W. of the Black Hills on the Powder River, and around the sources of the Big Horn. This formation consists of beds of clay, sand, sandstone, and lignite, and contains many fresh-water and land shells, with a few marine or estuary species; it also imbeds the remains of plants, saurians, turtles, &c. The beds of lignite, or Tertiary brown coal, are of unusual thickness and persistency.

Miocene Fresh-water Basin of the Niobrara and White Rivers.—According to Dr Hayden, the intrepid explorer of this region, the Miocene formation embraces five groups of strata. The lowest seen on Old Woman's Creek, and along the valley of the South Fork of the Shayenne, on Sage and Bear creeks, and in the valley of White River, consists of light-grey fine calcareous sand, plastic and ash-coloured clays underlaid by ferruginous sand and gravel; it is called the Titanotherium bed, from its containing the bones of a colossal quadruped of that name allied to Paleotherium. This deposit is nearly 100 feet thick.

The next group ascending, called the Turtle and Oreodon Bed, seen also on Old Woman's Creek, on the head of the South Fork of the Shayenne, on Sage and Bear creeks and White River, is a flesh-coloured argillo-calcareous grit, underlaid by sandy clay; it contains a profusion of mammalian and chelonian fossils, and is from 80 to 100 feet thick.

The third bed met with in the same localities consists of fine yellow calcareous sand, passing downward into an alternation of dark-brown clay and a light-grey calcareous grit; it imbeds layers of calcareous concretions, and a few organic remains.

The fourth group seen on the Niobrara and Platte and White rivers, and well developed near Fort Laramie, is a dull reddish-brown grit, or argillo-silicious stratum, with many layers of silico-calcareous concretions, passing into a fine-grained sandstone. It contains comparatively few fossils, and is from 350 to 400 feet thick.

The fifth and uppermost Miocene group, best developed around the upper portion of the Niobrara River, and in the region of Fort Laramie, is a coarse-grained sandstone, sometimes compact, sometimes incoherent. It contains great masses of conglomerate and layers of tabular limestone, slightly fossiliferous; it imbeds a few mammalian fossils, but these are in a fragmentary condition.

Notwithstanding the large number of species of molluscous and other remains found in both the Eocene and Miocene Atlantic tertiaries, it is worthy of note that very few of them, indeed not more than two or three per cent, are possessed in common by the two formations, showing a very remarkable extermination of the inhabitants of the ancient tertiary coast. This fact respecting the almost total revolution in the inhabitants of the tertiary waters, at the change from the Eocene to the Miocene deposits, is itself significant of a widespread alteration in the physical conditions of the region. This was no doubt a change in the level of the bed of the sea, amounting, probably, to its temporary desiccation, re-immersion, and almost certainly to a modification of its currents, its temperature, and the nature of its sediments, though the Eocene beds were neither permanently uplifted nor indurated, but left in their original horizontality beneath the ocean-level, as a floor for the reception of the parallel Miocene strata. There can be but little doubt that the changes here mentioned all came about, fitting the waters for the abode of new species, and even many new genera. How much actual time may have elapsed between the cessation of the Eocene and the beginning of the Miocene sediments, for the extirpation of the one group of living races and the creation and diffusion of the succeeding, we have no data for estimating, but that some interval elapsed is sufficiently obvious.

On the Pacific side of the continent the phenomena are somewhat different, the levels appearing to have been more disturbed than on the Atlantic border at the close of the Eocene period. But we know at present too little critically of the tertiary geology of California and Oregon to interpret safely what the revolutions exactly were at the several tertiary epochs. The effusion of volcanic materials early in the tertiary ages must have complicated greatly the tertiary physical geography of that side of the continent.

Pliocene and Pleistocene Strata.—Applying the terms Pliocene and Pleistocene to those tertiary deposits which were produced in the periods between the times of the Miocene formations and the recent or existing order of things, this designation will include several late tertiary tracts, not only on the Atlantic plain and on the Pacific slope, but in the interior of the continent in Nebraska. Very probably these deposits are not all of one age, but it is impossible, in the present stage of research, to place them under an exact chronology. It seems most probable that many of the so-called Post-pliocene fossiliferous beds of the Atlantic seaboard are contemporaneous with the superficial strata farther North which belong to the Pleistocene series. It will suffice for our present purpose to describe them as we know them.

Pliocene and Pleistocene Beds of Virginia and North Carolina.—The formation of Pleistocene age with which we are best acquainted is a thin deposit of shelly sands skirting the coasts of the Chesapeake Bay from the St Mary's River southward, and covering a broader belt of country on the Atlantic coast of Virginia and North Carolina as far as Pamlico Sound. These beds are characterised by shells, nearly all the species of which are identical with forms now occurring somewhere on the Atlantic coast, one or two of the most common species living now only in the warmer waters of the Gulf of Mexico. Mixed with these shells are the bones and teeth of several genera of extinct land quadrupeds: the fossil elephant or mammoth, the mastodon giganteum, and a species of horse somewhat larger than that now living. Still farther S. along the seaboard occur other modern tertiary deposits differing somewhat from these in composition, but apparently equivalent to them in age. They are characterised by the presence of fossil shells, and other marine and estuary remains, belonging to species now inhabiting the adjacent coast, associated with the relics of many interesting extinct quadrupeds.

Another Pleistocene deposit skirts the shores of Mobile Bay and the adjacent coast of the Gulf of Mexico. This contains some beds abounding in fossil shells identical with species now living in the Gulf. It is very probable, indeed almost certain, that there exist similar uplifted recent tertiary beds in many other places, both along the Atlantic coast and that of the Gulf of Mexico, but they have been too imperfectly examined to admit of being here described. Strata of Pliocene age, of lacustrine or fresh-water origin, exist in the interior of the continent. Recent researches render it probable that some of the more superficial tertiary strata of the W. coast of the continent, especially in California, appertain to this period; indeed, at several localities on the coast of that State, raised beds occur, abounding in marine shells nearly identical in species with those now existing in the Pacific, but associated with mammalian remains that imply an elevation at either the Pliocene or Pleistocene periods.

Pliocene Strata of Nebraska.—An upper tertiary formation, referred by Meek and Hayden to the Pliocene era, is somewhat extensively developed on the Niobrara River, spreading Westward from the mouth of Turtle River. It occurs in the valley of the Platte, also in the Bijou and Medicine hills, covers a large area on Loup Fork, and is thinly spread in the valley of White River. The deposit consists of brown incoherent sand, imbedding remains of mastodon, elephant, &c.; loose sand and gravel; a yellowish-white grit; a greenish-grey sand, containing a greater part of the organic remains of the formation; a dark-yellow sandy marl; and a yellowish-grey calcareous grit, with many layers of concretionary limestone, containing fresh-water and land shells closely allied and perhaps identical with living species. The thickness of the whole deposit is estimated to be between 300 and 400 feet.

The organic remains hitherto procured from the Nebraska Pliocene strata belong to the new Ruminant genera, *Merycodus*, *Megalomeryx*, *Procamelus*, three species; *Merychyus*, three species; and a deer, *Cervus Warreni;* to the many-toed genera, a species of rhinoceros, a mastodon, and an elephant; to the solid-footed races, six species, two of them to *Hipparion* or *Hippotherium;* two to *Merrichippus*, another horse-like genus; and two to the genus *Equus*, or true horse. Besides these, Professor Leidy has discovered among the remains a porcupine and a beaver, together with seven carnivorous species—namely, *Laptarchus primus*, *Felis intrepidus*, *Ælurodon ferox*, *Canis Sœvus*, *Canis temararius*, *Canis vafer*, and *Canis Haydeni*, besides a chelonian or turtle, *Testudo niobrœnsis.*

Californian Pleistocene Beds.—California contains several interesting pleistocene deposits, and it is probable that there are others farther N. on the Pacific Slope in Oregon. The recent researches of Mr Blake and Dr Trask have shown that several of the lower tracts on the W. side of the Sierra Nevada are of this age. The longest Pleistocene belt fills nearly the entire length of the valley of Middle California, or that of the Sacramento and San Joachim rivers, including the basins of the Tulare lakes. This plain or trough of pleistocene is the main auriferous region or gold basin of California; but the tertiary alluvium is not confined to the bed of the valley, it penetrates the lateral ravines at the base, and even ascends the longer ravines high upon the flanks, of the Sierra Nevada. To the west of this main belt occur two or three other parallel strips of upraised post-pliocene. One of these fills a part of the Nassa valley, another lesser one occurs in the Santa Clara valley, and a third runs from the Bay of Monterey up the valley of the San Antonio. Perhaps the most interesting of all the post-pliocene tracts belonging to the Pacific Slope is that which extends N. from the head of the Gulf of California into the Colorado Desert. This is a low plain or valley, having a well-defined sea-margin or ancient coast-line for its boundary, and consists of a fine silt or clay, the deposit evidently of the waters brought into the Gulf of California by the Colorado River. The remarkable feature connected with this valley-deposit is, that a large portion of its surface is at and below the existing level of the ocean—a region, in other words, of continental depression. Barometric measurements show that some parts of the ancient gulf-margin referred to now stand 80 or 90 feet beneath the mean level of the sea; Mr Blake and other observers testify that at their barometric stations the plain visibly sinks from both sides towards the centre at an inclination quite visible to the eye: so that they infer that the middle parts may be even between 200 and 300 feet lower than the surface of the sea. A very slight swell of the plain a little North of the mouth of the Colorado seems to have insulated this depressed area from the waters of the gulf; indeed, it is very probable that the same movement of the earth's crust, doubtless some earthquake convulsion which lifted the plain in this neighbourhood, depressed the district farther N. The whole phenomenon is thus easily explained on the supposition that the Gulf of California extended in the Pleistocene period to the head of this low plain, and that an earthquake movement of the whole region lifted slightly the surface from its previous level with a low swell or undulation transverse to the ancient gulf near the mouth of the Rio Colorado. The excessively dry character of the prevailing winds of this region will account for the absence of a lake in this depressed part of the Colorado Desert. The presence of much sea-salt in the soil, amounting in some localities to a white efflorescence upon the surface, like a permanent hoar-frost, shows not only how the ancient gulf-waters may have been evaporated by the parched atmosphere, but how those of any lake which may at first have existed there fed by the back-water of the Colorado in its times of freshets, may also have been drunk up. The Tulare lakes of the Joachim Valley offer at this time a condition of things somewhat parallel to that which is here assumed, for throughout the long dry season of California these are little else than broad level meadows, from whence the waters have been exhaled by the drying action of the climate, and only in the wet season are their wide marginal tracts covered with a thin sheet of transient rain-water.

The Pleistocene strata of Nebraska consist of yellow silicious marl, underlaid by clays and fine grits, in all from 300 to 500 feet thick. The *organic remains* are some extinct quadrupeds, mingled with species now existing; also a few species of Mollusca, of chiefly living types.

Fossils of the Atlantic Pleistocene Strata.—The Pleistocene beds on the Potomac River in St Mary's County, Maryland, contain, associated with several species now living in the Chesapeake Bay, an estuary shell, the *Gnathodon cuneatus*, now restricted to the warmer waters of the Gulf of Mexico; and the similar recent tertiary deposits on the Neuse River, Carolina, show a mingling of the gnathodon with shells of the Southern Atlantic coast. The more N. locality has produced no bones or teeth of extinct land animals, but from the Carolina formation have been procured those of the elephant, mastodon, and horse, as already mentioned. The modern tertiary beds between the Altamaha and Turtle rivers, Georgia, contain, along with shells of species now inhabiting the neighbouring waters, remains of the mastodon, elephant, horse, hippopotamus, bison, megatherium, and mylodon, these pachydermal and edentate genera pointing to an identity of period between the Georgian deposits and the superficial tertiaries of Patagonia, where Darwin and other naturalists found a similar association. Some of these species, the *Mastodon giganteum* and the *Elephas primogenius*, occur, as will be stated presently, in the upper deposits of the North American Pleistocene drift, showing most probably that all of these later tertiary formations were produced and uplifted about the epoch of the superficial boulder-deposit.

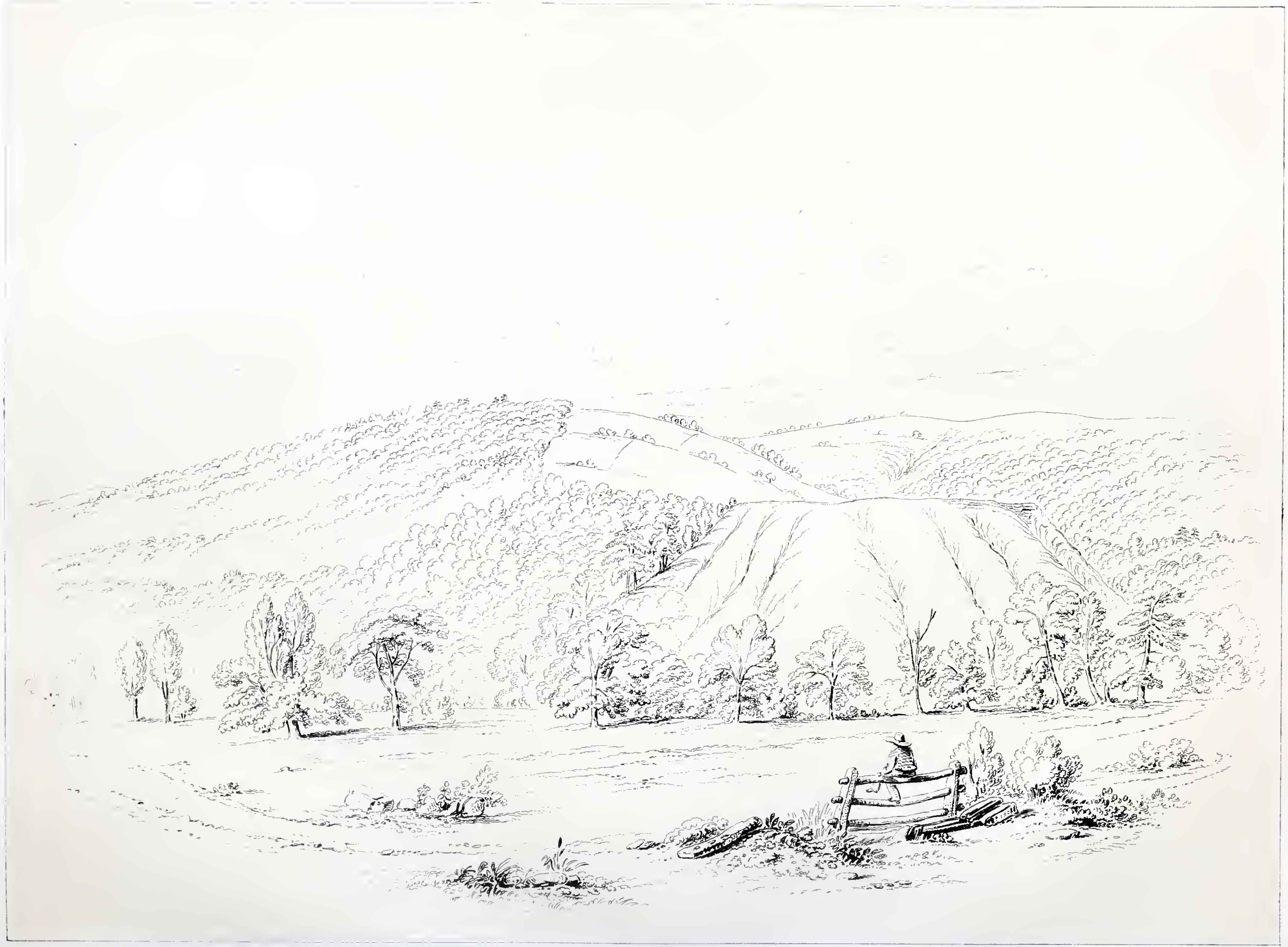
THE NORTHERN PLEISTOCENE, or Great Boulder-Drift.

Throughout the greater part of the continent of North America, from about the latitude of 40° Northward, the rocky floor of the country is covered to a greater or less depth with that well-characterised formation called the *Northern Boulder-Drift*. In many districts this is a complex group of deposits, consisting of three or more formations, denoting at least three distinct epochs, and at least three different conditions or changes in the physical geography. In the N.E. part of the United States, extending to the adjacent British Provinces, this triple division of the Northern Pleistocene Series is well characterised, and admits of the following brief description:—

The first or lowest deposit is a prevailing, indeed almost universal, stratum of boulder-drift, reposing immediately upon the rounded, scratched, and polished surface of the general rocky floor of the continent. This loose heterogeneous material is composed of gravel, sand, and clay, and boulders, more or less rounded, of all sizes, the whole rather promiscuously mingled, but generally stratified, the stratification being in oblique and often abutting planes of deposition, denoting turbulent and conflicting currents. This is the general character of the drift in all upland positions, and even in the river-valleys throughout New England and the Northern States. In some more restricted localities, immediately contiguous to the ocean, as around the harbours of New York and Boston, the drift has more the character of the European Boulder-clay, consisting of a mixture of sand and clay, destitute of lamination or stratification on the small scale, and imbedding boulders of various sizes irregularly scattered through it. The boulders and pebbles in both the stratified and unstratified drift are themselves smoothed and striated, and blunted and rounded on their edges, showing signs of having undergone a great amount of attrition. The materials composing this remarkable formation belong invariably to rocks lying N. or N.W. of their present positions, and in many districts are traceable to remote localities,—across broad plains, deep valleys, great sheets of water, and over chains of hills, and even across lofty mountains. The boulders have evidently not radiated from any centres of dispersion; they exhibit a progressive diminution of size as we trace the same kinds S. from their parent rocks, though solitary blocks of large dimensions occur within and upon the general mass of sand and gravel. But even these boulders show the same rapid diminution in size as we follow them S. In wide and level districts the larger boulders are frequently seen uniformly but sparsely scattered over broad tracts of country. In other quarters, where the surface is more diversified, they sometimes form long narrow belts, the borders of which are sometimes remarkably parallel. The direction which the drift matter has taken conforms generally to that of the scratches upon the rocks beneath; and in the hilly districts of New England, New York, New Jersey, and Pennsylvania, it is for the most part obliquely across the crests of the mountains. Lower on the slopes, and in the beds of the longitudinal valleys, it conforms partially to the courses of the great hollows in their surface, as if at these lower levels it had been deflected into the previously established lines of easiest drainage. One essential phenomenon is the occurrence of rocks, some of them of considerable size, high on the slopes and summits of mountain-ridges and table-lands, a thousand or fifteen hundred feet above the level of their parent rocks.

Southern Limit of the Drift.—The S. visible limit of the continuous drift stratum, in the British Provinces and in New England, is the sea-coast. From the estuary of the Hudson it trends inland, following an irregular undulating line W., across New Jersey and Northern Pennsylvania to Ohio, and the States farther West. On the mountains and table-lands its position is invariably farther N. than on the plains and in the valleys between them. And it projects long tails far to the S. of its general average boundary, through the great N. and S. valleys which open S. towards the Atlantic and Gulf slopes, through the Appalachians, and across the water-shed S. of the great lakes,—the gravel and boulder matter even extending hundreds of miles down the valleys of the Delaware, the Susquehanna, the Alleghany, and the Mississippi rivers. It seems to have been arrested in its progress S. by the high table-land of Northern Pennsylvania, only the lowest depressions in this plateau admitting it farther Southward with the slope of the continent.

Striated Rocky Floor of the Drift.—The rocky surface upon which the drift reposes is everywhere furrowed and smoothed, except upon the steep Southern or lee sides of the hills, where the outcropping strata retain an unworn or craggy aspect. The smoothed and striated region is nearly coextensive with the area covered by the drift, only the furrows grow faint, and even cease altogether, in many elevated districts, at a point some miles to the N. of the ultimate margin of the attenuated bed of drift or of scattered boulders. This worn condition



W. & A.K. Johnston, Edinburgh.

SPANISH HILL NEAR ATHENS TIOGA Co PA

of the surface occurs at all altitudes, from the sea-level to the summits of the loftiest mountains in New England, New York, and Northern Pennsylvania. Only the culminating peak of Mount Washington, the highest point S. of the valley of the St Lawrence and great lakes, and 6228 feet above the ocean, appears to have escaped the abrading and polishing action, all the other hills of the same group, some of them more than 5000 feet high, having their very summits visibly worn. The scratches upon the rocky surface do not radiate from the high mountain-centres any more than do the materials which cover them; but they maintain, throughout New England, Pennsylvania, and the great plain West of the Appalachians, a very general average direction towards the S.S.E., or in the direction of the maximum slope of the continent. This course is most constant upon the open plains, high table-lands, and mountain-crests; but within the valleys, and at the feet of the ridges, a deflection is observable; and the new direction imparted is constantly such as a moving fluid or plastic mass would take in sweeping round or past the obstructing barriers. The striæ present a general parallelism in direction; but wherever the rocky surface is uneven, they exhibit a considerable deviation from one course, later grooves crossing earlier ones at various acute angles, some of which amount to 30°. The striæ are, moreover, not rigorously straight, but curve slightly to conform to inequalities in the shape and hardness of the resisting surfaces.

Pleistocene Fossiliferous Clays and Sands. — From the coast of Maine westward to the basin of Lake Ontario, and from the estuary of the Hudson northward to that of the St Lawrence, a deposit of blue clay and sand occupies the valleys of many of the rivers and lakes at all levels above the tide, and to a height of more than 400 feet in the valley of Lake Champlain, where its elevation is at a maximum. In the great valley occupied by Lake Champlain and the tidal portion of the Hudson, this stratum consists chiefly of a tenacious blue clay, with some beds of argillaceous sand towards its lower limit; and the same clayey character belongs to the formation which fills at a lower level the estuaries of the Connecticut, the Kennebeck, the Penobscot, and the St John rivers. In the valley and estuary of the St Lawrence the prevailing materials are sands and very sandy clays. Both the blue clay of Lake Champlain and the Atlantic rivers, and the more sandy beds of the St Lawrence, contain marine shells; in some localities, in great abundance, about twenty-three species having been identified. All of these, without exception, are forms now living either on the coast of Massachusetts or in the Gulf of St Lawrence, and are not therefore peculiarly sub-Arctic forms. The two most generally diffused species are the *Saxicava rugosa* and the *Tellina Greenlandica*, both of which are now abundant in Massachusetts Bay. It would appear that this stratum, having its maximum present elevation above the sea-level in the district of Lake Champlain, declines gradually in height both Southward and North-eastward. Its mean level in the plain of the St Lawrence, at Montreal, is only about 200 feet, though some of its materials, displaced and re-deposited, probably by the inundation which accompanied the uplifting and draining of the valley in which it was accumulated, are found lodged in small patches at considerably higher levels in the recesses of the bordering hills, particularly on the Montreal Mountain.

This marine Pleistocene formation has been appropriately named by Professor E. Desor the Lawrentian Clay.

Fresh-water Pleistocene of the Western States.—An extensive deposit occurs South of Lake Erie and Lake Michigan, and in the peninsula between them, which is probably nearly contemporaneous with the marine Lawrentian; for, like it, it rests generally upon the continental or general boulder-drift. It contains a few lacustrine shells, and fragments of leaves and wood, and seems to have been accumulated, like the Lawrentian formation, in the period of quiescence which intervened between the close of the great first drift-deposit and that later or last disturbance of the levels of the land which uplifted the Lawrentian formation, and at one and the same time drained the tidal valleys and straits in which it was collected in wide spaces around the present lakes. These fresh-water beds seem, in part at least, to be the products of swamps and lake margins. Covered as they are very generally by superficial sands, and even a sparse strewing of boulder gravel, they appear to belong to the middle Pleistocene era, or the period of repose which separated the convulsed epochs of the earlier general and the later local drifts.

Later Local Drift.—In the valleys of the Hudson and Lake Champlain, and elsewhere, the Pleistocene marine clay is covered to a shallow depth with a stratum of drift composed of coarse sand, gravel, and boulders, resting on its denuded and trenched surface. No one general direction or Northern source can be assigned to this upper deposit, its gravels and erratic blocks appearing rather to be derived from the more ancient general drift of the adjoining hills, re-dispersed by some aqueous movement upon the surface of the fossiliferous clays and sands. A similar superficial drift-like material, including in some districts erratic boulders of large dimensions, will be found to overlie very generally both the marine and the Western lacustrine middle Pleistocene deposits. A ready explanation of the origin of this newest Pleistocene deposit suggests itself when we consider the nature and energy of the crust-movements which lifted the Lawrentian clays and sands to a height, in one locality at least, of not less than 500 feet, and which drained wide tracts of the upper Lawrentian lakes. The mere agitation or pulsating movement of the crust would suffice, if unaccompanied by any permanent uplift of the land, we would think, by lashing the waters of the tidal estuaries in one quarter, and of the lakes in the other, to strew a portion of the older drift bordering all those basins in wide dispersion upon the top of the more tranquil sediments; but if such a pulsation of the crust were accompanied with successive paroxysmal liftings of wide tracts of the land, then the inundation would take the form of stupendous currents, the strewing power of which would be adequate to any amount of superficial transportation, even to the remote transportation of the largest erratics.

CONDITIONS OF THE PHYSICAL GEOGRAPHY ATTENDING THE PRODUCTION OF THE PALÆOZOIC STRATA OF THE UNITED STATES.

SOURCES OF THE SEDIMENTARY MATTER—STATE OF THE WATERS—CHANGES OF LEVEL OF THE SEA-BOTTOM—HORIZONS OF CONTINUITY AND DISCONTINUITY.

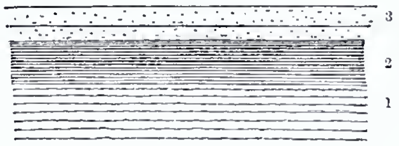
PRELIMINARY CONSIDERATIONS.

Before entering upon a discussion of the physical conditions which witnessed the deposition of the Palæozoic strata of Pennsylvania, and the Appalachian Basin generally, it will be expedient to recall attention to two or three deductions of modern geology, which may be accepted as criteria in our reasonings. As we are endeavouring, from a wide assemblage of facts relating to the composition, dimensions, and organic and other contents of the strata, and from their mutations, to deduce the conditions under which they were deposited, or gain some insight into their physical geography, the depth of the waters, their shore limits, the directions and relative force of their currents, and the elevations and shiftings of their successive bottoms, we must consider, in the outset, how we establish the preliminary inferences upon which we build our final conclusions.

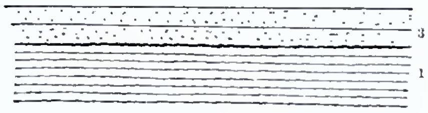
First, as regards the evidence of the presence or absence of depositing waters, or of sedimentary action. Though a few speculative geologists, in their desire, independently of observation, to resort to alternate changes in the levels of the earth's crust to meet the emergencies of theory, are in the habit of contemplating submersions of the land beneath the sea, where there are yet no vestiges, organic or inorganic, of its presence at the epoch, we are warranted, I think, in stating, as an axiom of the science, that every current or over-resting sheet of water has left *some* permanent monument or trace of its presence or passage, and that wherever, between two strata or ancient surfaces, known to have been formed at an interval of time, nothing whatever of a sedimentary sort is interposed, we are to conclude that the vacuous space was dry land. It is not conceivable that the waters of the globe, known to be susceptible of holding their finer sediments in partial suspension for weeks, and months even, and of wafting them for hundreds, nay, even thousands of miles, and to have teemed, too, under every climate and condition, with millions of microscopic animal and vegetable organisms, could ever have rested long, or even have flowed transiently over any ancient surface now exposed to our view, without having left behind them some sediments as indelible records of their existence. It has been alleged that the deposits of one epoch may have been entirely removed by the erosive currents of a subsequent ; but such complete obliteration is inconceivable, except for comparatively very narrow areas, for the same currents that could plough up and transport all the materials of the floor over which they moved, must have dropped those materials elsewhere on the confines of the eroded district, and under conditions, and bearing contents, capable of betraying in all cases the source from whence they were derived. It should be borne in mind that, as earthy sedimentary matter is to a large extent insoluble and indestructible by water, and all moving water is formative as well as destructive, or must deposit what it has lifted, it is always in the geologist's power to investigate the supposed removal of a stratum by an inductive study of the phænomena open to his observation. And until he can prove that there has been at least one formation completely removed from off a wide area of the earth's crust, over which it was deposited, he is not entitled, upon sound rules of scientific reasoning, to infer that it was ever present there. The recent discovery of minute organisms covering nearly the whole bed of the North Atlantic, and wide tracts in other seas, at profound depths, where previously no life nor vestiges of life were supposed to exist, but in their place only darkness, stillness, perfect rest, and an entire absence of the vital force, settles once for all this important fundamental question. If we are justified in attributing a watery origin to certain sheets of matter because they indicate deposition and strewing, and contain shells, scales, and bones, the obvious relics of creatures in affinity with the known aquatic races of the present day, we are equally warranted in rejecting the conception of a submersion of any district until we can there find some such evidences of the waters, or some independent proofs that the materials the waters must have contained and precipitated were once there, and were subsequently swept away.

One chief object of the present Chapter being to trace the several Palæozoic formations of Pennsylvania, as independent deposits or sheets of matter, through their various phases of composition and thickness across the State, and thence out into the great Appalachian basin of the continent, even to its distant shores, it is necessary that we should keep our attention, not only upon the strata themselves, but upon the horizons or ancient surfaces which divide them. Before attempting this, it will be expedient to settle a few points of definition in regard to the conditions under which contiguous strata are superposed.

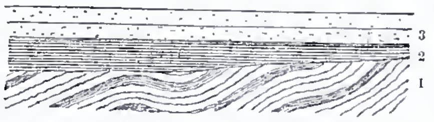
Fig. 585.



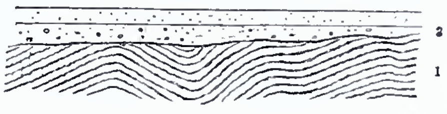
1. Conformable Continuous Sequence.



2. Conformable Interrupted Sequence.



3. Unconformable Continuous Sequence.



4. Unconformable Interrupted Sequence.

Reviewing all the possible relations of superposition, it will be found that they arrange themselves under four categories. They are illustrated in the diagrams here annexed.

First, Deposits of successive dates may be superposed in regular parallel order, so continuously as to mark no pause in time, or interruption in the formative process; and even the transition from one formation to another may be so gradual, both in the substitution of a later sediment for a preceding, and of one set of organic remains for another, as to imply no positive cessation of time or action. Such a following of one formation by another, I propose to entitle a *conformable continuous sequence*.

Secondly, One stratum or set of strata may immediately overlie another with apparently perfect parallelism of their beds, and yet their plane of contact may represent a great interval of time, and a total change of the physical sedimentary conditions ; in other words, there may be an absence of strata, or even of whole formations, or entire series of formations, developed in other districts of the same or of other waters, and recording a long period of geological time. Where, from independent evidence of stratification and fossils, we are convinced that the contact is between deposits thus separated in age, though physically joined, and to all appearance directly sequent, we may entitle the relation a *conformable interrupted sequence.* This condition implies a cessation of sedimentary action through a longer or briefer period, and we know of no change but that of elevation above the water or into dry land compatible with it, at least for any length of time. This juxtaposition of rocks remote in age, where the lower were still level at the date of the deposition of the upper, proves not merely a lifting of the watery floor to the level of dry land, and its reimmersion, but a movement unattended by any narrow or steep undulations ; or in other words, it indicates merely a broad general bulging of the crust. Traced far, however such instances of parallelism will almost invariably be discovered to exhibit a change to unconformity, implying the universality of a law previously announced, that every displacement of the level of the earth's crust has been, and still is, somewhat undulatory.

Thirdly, There is a third condition of contact, where the upper group of beds reposes on the lower at a greater or less angle, their relative attitudes implying an uptilting or loss of levelness in the inferior before the superior were deposited, even though we are assured from their organic contents that they were strictly consecutive in time, or so nearly so that no independent formation, or group of organic beings, elsewhere occupied any part of the earth's surface within the interval. Such instances of superposition exhibit a physical break, but not a break in time. This relationship may be entitled an *unconformable continuous sequence* of the strata.

Fourthly, The remaining category under which two sets of strata may rest in contact is that where they exhibit not only an absence of parallelism, but an omission of one or more formations known in other districts to overlie the lower, and underlie the upper. This state of things implies not merely a disturbance of the inferior deposit, from the approximately horizontal position in which it was formed, but its elevation into dry land, with a lapse of time and a reimmersion of the mass without a regain of its original level attitude, all prior to the deposition of the formation resting over it. Such a condition, familiar to geologists as the commonest instance of unconformity, I propose to entitle an *unconformable interrupted sequence.*

I have presented the above definitions as essential to a clear understanding of the nature and relative magnitudes of the planes of discontinuity which separate the Appalachian strata, and, by interpretation, the crust-movements which preceded and followed the various formations which successively occupied the floor, or portions of the floor, of the Appalachian sea in Pennsylvania and elsewhere. It is only by holding these distinctions well in view, and by studying the corresponding breaks in the sequence of the organic remains imbedded in the strata, that we can hope philosophically to group, classify, and name our stratified rocks, and reconstruct in imagination the successive phases of the ancient physical geography of this quarter of the globe.

It should be observed, that we frequently meet with each of the four above-described conditions of contact of the strata, where the uppermost, though deposited horizontally, have undergone, together with those below them, great displacements from their primary level posture. However uptilted they may be, the two sets always retain, of course, their previously-established relative attitudes.

We may assume it also as an established law, upon which we may safely rely in our geological reasonings, that the relative coarseness or fineness of the sedimentary matter in a given stratum measures approximately the relative strength or feebleness of the watery currents that strewed them; and furthermore, that the degree of thickness of a land-derived or mechanically-formed deposit, is a criterion of its relative proximity to the ancient shores from whence it was swept. Guided by the familiarly-known transporting functions of moving water, in which we witness every gradation of velocity, from speeds too swift for any deposition to motions too sluggish for the further floating of the suspended matter, we must infer that the greater number of sea-borne sediments, not merely sheets of gravel and sand, but the widest layers of clay, are in their component beds, and in their aggregate bulk, very thin, even to a feather-edge, at both their landward and seaward margins;—their landward, from excess of velocity; their seaward ones, from exhaustion of material. It is plain that, by carefully observing in any stratum all its gradations in respect to its aggregate thickness, the coarseness of its constituent fragments and particles, the nature of its organic remains as implying shallow or deep waters, and the quality of its materials as traceable to comminuted rocks of the dry land, or to chemical precipitates derivable only from water, the geologist—if the scale of the deposit is large—is enabled, by assembling his data, to ascertain, with considerable accuracy, the quarter whence the formation was derived, and the relative strength and depth of the transporting currents; indeed, if he proceeds with caution, he may, by summoning to his aid the facts and deductions of physics on the one hand, and those of natural history on the other, gain not a little insight into the physical geography of the globe, at its best recorded successive epochs. This attempt at a restoration of the ancient geographies of the earth in the sense of the relations of its lands and waters, and the distribution of its living tribes, is one of the highest aims of geology, in the cautious inductive pursuit of which the science is gradually taking rank by the side of astronomy itself, for the sublimity of the field it opens, and its marvellous capacity of revealing the unknown. Humbly hoping to contribute some facts, and a few generalisations, as materials towards the construction of an Ancient Physical Geography for North America, I shall venture, in the following pages, to present the observations furnished by the Geological Survey of Pennsylvania, in connection with some derived from the best explorers who have been studying the other different districts of the ancient Palæozoic sea along its Northern, Western, and Southern shores, and throughout its middle tracts.

DEPOSITIONS AND DISTURBANCES OF THE PRIMAL PERIOD.

Commencing our description of the conditions of deposition and movements of the Palæozoic strata of Pennsylvania, and the Appalachian basin with the Primal series, the first feature which claims our attention is the prodigious thickness and great general uniformity of composition of certain members of this widely-extended deposit. Viewed broadly, it may be regarded as an enormous accumulation of a very ferruginous sandy clay, the lower and upper Primal slates imbedding comparatively thin sheets of coarser fragmentary matter; a conglomerate at the base of or within the lower; a white evenly-constituted sandstone at the base of the upper. The entire argillaceous mass has evidently been derived from a S.E. or S. source, and from a region in those directions as far away from the present N.W. outcrop of these strata in the South Mountain or Blue Ridge, as the lower portion of the Atlantic slope in Virginia, the Carolinas, and Georgia. Along their line of outcrop, at the edge of the great Appalachian valley, these Primal slates appear to cease towards the N. ere we reach the Delaware River, for we have but imperfect traces of them through New Jersey, New York, and the W. side of New England. In consonance with this fact, they thin away N. and N.W. probably near the same latitude, for they nowhere rise to the day in Canada, nor along the shores of Lake Superior, nor in Wisconsin and Minnesota; but the Primal white sandstone, or great Arenaceous formation of the series, rests everywhere throughout this vastly-extended ancient coast-line, on an earlier metamorphic or Azoic system of rocks, and is in turn almost immediately overlaid by the sandy magnesian limestones of the Auroral series. How far to the S.W. the main body of the Primal series, the Primal slate, extends, I am at present unable to assert, but I believe it ranges in the Blue Ridge and Atlantic slope into Alabama. Some conception of its geographical and vertical dimensions may be gained by reflecting that it constitutes apparently a very large portion of the broad chain of the Blue Ridge and of the Atlantic slope through a breadth of about 40 or 50 miles from the Susquehanna to Georgia; and where the thickness of the whole series is susceptible of estimation, it cannot be less than 5000 feet, and it is probably much more.

So wide a deposit, derived evidently from the comminution of Gneissic or other older metamorphic rocks situated to the S.E. of its present outcrops, can only have proceeded from a very extensive degradation of a wide expanse of dry land, commencing in the lower portion of the Atlantic slope, and spreading where we have now the Tertiary sea-board plane, and even the waters of the Atlantic. It is obvious from the unconformable superposition of the Primal series upon the Gneissic system, that the deposition of the Primal was preceded by a wide movement of depression of its Gneissic floor, letting on the waters of the Appalachian sea, where we have now the upper half of the Southern Atlantic slope, but not permitting them to overflow the surface in those N.E. districts where the Primal white sandstone is the lowest Palæozoic formation resting against the Gneiss or the Azoic. This subsidence below the sea-level evidently began in the S.W., or S., as the deficiency of the lower Primal rocks in the N.E. plainly proves. The movement of the crust here spoken of must have left above the waters a large tract of continent, or at least a great chain of islands to the S.E. of the present Atlantic plane; and as so many of the subsequent formations of the Appalachian region point as clearly as the Primal to an E. and S.E. source for their land-derived materials, it is manifest that the supposed Eastern lands, with more or less of fluctuation in their limits, must have remained such even to the close of the Carboniferous period, or till the uplifting of the latest Coal-measures.

The coarse stratum of silicious conglomerate intercalated in the Primal lower slates, far below the horizon of the white sandstone, is manifestly a S. rock, for it does not reach N. to Pennsylvania, and seems to have its fullest development in Eastern Tennessee. It was produced, obviously, by some strong paroxysmal movement interrupting the quiet actions which were introducing and dispersing the sandy mud of the Primal lower slate, and pushing into the waters a column or broad sheet of angular fragmentary matter.

The conditions attending the deposition of the Primal white sandstone, or Potsdam sandstone, must have been very peculiar. If continuous as a single sheet of pure arenaceous rock, or even approximately so, as a series of thinning and thickening deposits embraced within nearly one horizon, or reposing on one clayey floor, it is one of the most remarkably persistent strata in the purity of its quartzose composition, and the constancy of its type, and its organic contents, which geological research has anywhere disclosed. From all the evidence now in our possession, it appears to underlie the entire Appalachian basin, ranging in one grand line of outcrop N.E. from Alabama to the St Lawrence, thence W. along the N. shore of the ancient sea to Minnesota, and rising in Missouri midway between these starting and terminating points. While it thus margins and probably spreads uninterruptedly under this wide area of more than 1000 miles diameter, it retains its simple condition of a nearly pure white sand, and is apparently nowhere more than a few hundred feet in thickness. That it was deposited in comparatively quiescent waters, and not from turbulent currents, is plainly evinced in the remarkable uniformity in the nature and size of its particles, in its freedom from heterogeneous conglomerates, and, indeed, from all pebbly masses, except some local beds of quartzose gravel, and strikingly in the universally perpendicular position of its long, slender, delicate, stem-like fossil, the *Scolithus linearis,* which seems to have been enclosed by the settling sand with as little horizontal bending motion of the stalks from any current, as when a field of standing corn is enclosed and bedded up in gently-falling snow. Whence could have arisen so very wide and uniform, and yet so gentle a dispersion or precipitation of this great floor of sand of nearly snowy whiteness? The regular bedding of the material, and its thin partings of almost impalpable clay, prove that the waters did possess some horizontal motion. Was this of the nature of a continuous systematic circulation like that now visible in the North Atlantic and some other seas? or was it intermittent without being paroxysmal, like the tide-wave currents stirring the beds of the broad shallow estuaries, such as those bordering the Gulf of Mexico at the present surface? Whence was derived so pure a sheet of unmixed quartzose sand? A mere *sorting* action of the waters operating upon mixed mineral sediments could scarcely have spread out this pure sand over such a breadth of floor, nor so very uniformly, but would have left large deposits of extraneous matter, and have intercalated many beds of gravel and clay. And to what source also are we to look for so prodigious a quantity of unmingled quartzose matter? May we not conjecture that this great sheet of white sand, unlike any sediment we can imagine to have come from the disintegration of the Gneissic or any other group of the older rocks, was supplied from the great dykes and veins of auriferous quartz, which, upon independent grounds of geological evidence, we are induced to infer, issued about this epoch in a melted condition through the rents and fissures of the crust over all the region of the Atlantic slope, and elsewhere around the Appalachian sea. It is but a conjecture, though in accordance, I think, with geologico-chemical facts, that outgushing bodies of this quartz, mingled with volcanic steam, and suddenly chilled and pelted upon by cold and heavy rains, may have been granulated into sand, as would occur with heated unannealed glass, and then washed in copious streams into the broad, shallow, and tide-moved sea, and there gradually dispersed and precipitated.

The waters of the Appalachian sea in the Primal ages would appear to have been as tranquil as those of other later periods. The clayey matter of the slates or shales denotes, by its finely-comminuted condition, the gentleness of the in-wafting currents; and the immense thickness of the deposits, the enormous time it occupied in collecting. The period was one of vast duration;—an enormous age of quiet sedimentation, with almost no life in the wide turbid sea.

A somewhat abrupt disturbance of the levels of the surface must have attended the rather sudden cessation of the previous prolonged precipitation of the Primal upper slate, and this movement was evidently an unequal one—an elevation and a subsidence of the floor of the sea which contained the Primal mud. It resulted in a totally new condition of the waters. The introduction of the Primal clays from the S.E. was stopped for ever—not suspended, as during the precipitation of the white sandstone; and in their place there commenced an immensely-extended gradual deposition of the materials of the sandy magnesian limestones of the next or Auroral period. This cessation took place at the beginning of the Upper Clay period in the N.E., and at its close in the S.W. The transition cannot have been a violent one, for almost no pebbly beds marking an active rush of waters are discoverable at the passage from the one formation to the other, but the two groups alternate their deposits through a thickness in some places of many hundred feet, one or more beds of the limestone being interstratified with the slate before the great body of the limestone commences. As the lowest Auroral formation, in Auroral calcareous sandstone, is absent with the Primal upper slate E. of the Schuylkill, the hiatus of two formations produces a conformable interrupted sequence.

Palæontological Break.—Throughout the Appalachian chain the Primal series contains only three or four fossils, two *Lingulæ* and the *Scolithus* in the white sandstone, and a vaguely-defined plant, at present the oldest known relic of organic existence in America, or perhaps in the world. But in Wisconsin, near the N.W. shore of the Primal sea, the white sandstone imbeds on a succession of thin floors some seventeen more species, among them some curious trilobites. Two of the seventeen are forms common to the E. outcrop, so that the total number of species yet defined is only about eighteen. Now it is remarkable that not one of these is to be met with in any of the formations of later date, though these were produced under circumstances especially favourable to the existence of organic beings. It thus appears that the physical revolution which cut off the Primal deposits, and fitted the ocean for the reception of the Auroral, *completely exterminated the previously-existing races.*

Here, then, is one of the most decided palæontological breaks, or epochs of discontinuity in the organic world to be met with in the whole succession of our ancient Palæozoic formations.

DEPOSITIONS AND DISTURBANCES OF THE AURORAL PERIOD.

We have seen, from foregoing descriptions of the Auroral strata of Pennsylvania and other districts, that it consists largely of a sandy magnesian limestone, which terminates towards its base, from excess of sand, in a calcareous sandstone, and that it is only towards its upper limit that the rock passes to a nearly pure carbonate of line, or becomes at all crowded with fossils. We have also noticed that the whole mass is enormously thick at its S.E. outcrops, throughout the Appalachian chain, from Alabama to the St Lawrence, and that, though much thinner along the N. border of the basin, it is still largely developed, upon its N.W. and W. margin, in Wisconsin, Iowa, and Missouri.

As the chief deposit of the Auroral series, the magnesian limestone exhibits its greatest development along its most S.E. limit, having a thickness there of some 4000 feet or more; and as it declines in bulk N. and N.W., it is manifest that it had a S.E. or S. origin, or at least that the conditions for its production were in fullest energy in those quarters; and it is equally obvious that it must have existed, in those directions, far beyond its present boundary, since we cannot suppose the deposition to have been thickest just at its margin. We are compelled, on the contrary, to suppose that, as all marine deposits must, it commenced geographically with a thin or feather edge, and, gradually deepened seaward. Indeed, judging alone from a comparison of its mass in different quarters, we are led to infer that its existing S.E. outcrop in the Appalachian chain occupies rather a mid-sea position in relation to the waters in which it was precipitated. Very possibly, however, the Appalachian ocean of the Auroral period was, like most of the oceanic basins of the world at the present day, deepest towards one side; and that this broad channel, stretching N.E., and shoaling towards the N. and W., was the region of most copious deposition of the material.

The striking increase in the magnitude of the cherty member of the formation, as we trace it S.W. along the great Appalachian valley into Central Virginia, and indeed into East Tennessee, supports the view here taken of a S. or S.E. development of the whole mass.

Respecting the origin or source of the ingredients of this stupendous deposit, it is not easy, in the present state of our knowledge, to offer more than some plausible conjectures. Being in the main a triple mixture of carbonate of lime, carbonate of magnesia, and quartzose sand, with a little alumina, and carbonate or oxide of iron, we have, in the first place, to account for the two first-named ingredients. These constituents of many great formations, of all geological ages, are by some geologists regarded as derived almost exclusively from shells, corals, and the exuviæ of various minuter marine creatures, triturated into an impalpable calcareous sand or mud; but by those of another school they are attributed in large part to a chemical precipitate of the carbonates of lime and magnesia, from waters sufficiently charged with carbonic acid to hold these salts temporarily in solution. Neither of these hypotheses meets the primary difficulty of finding a source for the enormous amount of the carbonates, combined with but little foreign matter, which this and other great limestone formations exhibit, under circumstances that almost preclude our tracing them to a solution of any of the pre-existing formations or mineral masses of the crust. In no region of the ancient metamorphic and igneous rocks, encompassing the present limits of these old Appalachian formations, do we discover any large mass, aqueous or Plutonic, of either pure or magnesian limestone, whence, by solution or by washing, so pure a deposit, or one even one tenth or one hundredth part the thickness of this mile-deep formation, could be derived. In truth it is, if not absolutely, very nearly the most ancient calcareous stratum known upon the continent. To what more primordial source, then, are we to look for its ingredients? Scarcely to the minerals of the crystalline and semi-crystalline Gneissic and Azoic strata, or to the comparatively limited granitic and other Plutonic dykes. The predominant constituents of all these masses are silex and clay, the former nearly fifty per cent, the latter about seventeen per cent; whereas the calcium and magnesium, the metallic bases of the lime and magnesia, scarcely exceed five per cent each. There was evidently some other hitherto unexplained source whence the early Palæozoic waters of the globe received their long-continued, gradual, but, in the aggregate, most prodigious supplies of the carbonates of lime and magnesia. To trace them, as some do, to submarine volcanic emissions, is to contradict all analogy with the known nature of modern volcanic products and volcanic functions; indeed, we have the amplest geological evidence that the ancient igneous eruptions through the crust were accompanied with as small a proportion of these mineral substances, so indispensable to the solid skeletons of corals, shell-fish, and many other marine races, as the modern volcanic lavas.

Concerning the origin of the quartzose sand so abundantly dispersed through the carbonates of lime and magnesia in nearly all portions of this formation, but especially in its lower member, the Matinal calcareous sandstone, or calciferous sandstone of New York, there is less obscurity. We have already seen, that around the N.E., N., and W. borders of the Appalachian sea, the Primal white sandstone constitutes the uppermost deposit of the series, there having been an elevation of the sea-bed in those quarters which shut out the clays of the Primal upper slate accumulated farther S. It is highly probable that the same movement lifted out the Primal white sandstone in a similar manner, S.E. of the Southern Atlantic slope, and thus around almost the whole periphery of the basin there must have been a broad expanse of freshly-risen, scarcely-cemented white sand, exposed to be washed by the tropic-like rains of that period into the wide, shallow, but constantly-sinking receptacle, and there commingled with the carbonates of lime and magnesia as these were being precipitated.

AURORAL BLUE LIMESTONE, CHAZY AND BLACK-RIVER LIMESTONE OF NEW YORK.

The upper member of our Auroral series, consisting, as will have been seen, of a regularly-bedded, evenly-deposited pure blue limestone, interstratified in some districts with layers of shale or clay, and distributed not only throughout the Appalachian chain of Pennsylvania, but as far in different directions as Alabama, the St Lawrence, and Missouri, must likewise have been deposited under conditions of extraordinary geographical uniformity. It is nowhere a thick formation, and appears to be almost entirely absent from some districts of the Appalachian chain. Elsewhere it has a depth of 200 or 300 feet. The most interesting general facts connected with it, are its repleteness in organic remains, and its almost entire freedom from the quartzose sand which is so general a constituent of the formation next beneath it, with which it is likewise contrasted, in containing a far less proportion of the carbonate of magnesia. The two formations differ greatly in the abundance of the fossils which they entomb. Thus Professor James Hall, after a long study of the species derivable from these deposits in New York, describes, in his Palæontology of that State, but thirteen forms from the magnesian limestone; whereas he defines seventy-seven as belonging to the Chazy, Birds-Eye, and Black River groups, or the local members of our Auroral blue limestone; and, what is remarkable, only one is common to the two deposits. There was evidently a physical change in the Auroral waters, and probably in the circumjacent land, at the coming in of this formation, some new condition checking the production of the carbonate of magnesia, and stopping entirely the introduction of the silicious sand, but favouring the inflow of a moderate amount of clay. This change was unquestionably owing to, or connected with, a wide movement of the bed of the waters, as shown by the *calcareous conglomerates*, an elevation amounting in some quarters to an actual lifting out to the level of the atmosphere of their magnesian limestone floor, as the absence of the Auroral blue limestone, and the Matinal limestone, and Matinal black slate over large tracts, abundantly establishes. Everything connected with the stratification of the blue limestone proves that it was deposited in comparatively shallow waters, and the structure of its fossils, and their high abundance, go to confirm this inference. We can hardly attribute the great increase in the amount of life, towards the later part of the Auroral period, merely to a change in the mineral sediments, for we find in other quarters of the globe, and even in other parts of the American Palæozoic strata, very magnesian and sandy limestones, though most usually sandy ones, which are not magnesian, quite full of organic remains. We are constrained, therefore, to think that their comparative paucity in the Auroral magnesian limestone was due to some other condition of the waters—possibly turbidness or temperature, or both—which accompanied the precipitation of its materials.

DISTURBANCES OF THE CRUST AT THE END OF THE AURORAL PERIOD.

Comparing the physical conditions of the later part of the Auroral period with those of the earlier part of the Matinal, as indicated by the strata and their organic contents, we discern signs of an important change throughout wide spaces of the Appalachian sea, especially in Pennsylvania and towards the S.W. Indeed, almost everywhere there is an important alteration in the materials of the strata—the Matinal argillaceous limestone, Trenton limestone of New York, including a much-increased amount of clayey and carbonaceous matter in the limestone, and many layers of pure clay or shale between its calcareous beds. That state of the physicial geography, whatever it was, which subsequently and for a long time permitted the deposition of widespread sheets of clay, had already begun with the commencement of the Matinal period. That there was a shift in the levels of the surface over many districts around the margin of the Auroral basin, is manifested in the circumstance that the Matinal limestone there spreads beyond the limits of the Auroral blue limestone, and reposes directly on the Auroral magnesian rock, in a *conformable interrupted sequence*, a condition which could only arise from a previous elevation of the sea's bed at the end of the Magnesian Limestone age, and a subsequent re-emersion of the surface at the beginning of the Matinal period, for the reception of its fossiliferous limestone. Such must have been the state of things over those portions of the edge of the basin, now the Appalachian or Kittatinny Valley of Pennsylvania, where the Auroral blue limestone is wanting, and the Matinal or Trenton limestone lies in contact with the magnesian. Such also was the condition in parts of Wisconsin, Minnesota, and Missouri. The shift of level of the sea-bottom towards the end of the Auroral period must have commenced with a somewhat violent agitation of the crust, for such is evidently the inference to be drawn from the conglomerate beds of very large limestone pebbles, seen near the superior limit of the Auroral magnesian limestone in the Kittatinny Valley. It was plainly no movement of elevation, since the Auroral blue limestone, and quite generally the Matinal limestone also, are wanting from the column of formations. The break of succession in which this movement resulted was greatest apparently towards the S.E.

The waters of the Appalachian ocean in the Auroral period were probably deep in the earlier ages, and deepest in the region of the present Appalachian Mountains, where the superior thickness of the great magnesian limestone implies either this condition or a more rapid subsidence of the sea-bed, and a more copious introduction of material. But this more copious precipitation of an aqueous sediment itself denotes a greater depth or mass of water.

PALÆONTOLOGICAL BREAK BETWEEN THE AURORAL AND MATINAL SERIES.

This transition from the Auroral to the Matinal deposits was accompanied by an almost entire extinction of the numerous marine races which lived in the Auroral waters, and heralded the introduction of still more numerous groups of kindred species. Indeed, as I shall elsewhere show, there appeared, with the almost total change in the species, quite a number of new genera. According to the tables of Professor Hall, the number of species restricted to the Auroral blue limestone, as hitherto examined in New York, is about seventy-seven, whereas the number peculiar to the Matinal limestone (Trenton) is one hundred and eighty-eight, while there are but three other species common to the two formations. Here, then, there is a palæontological break or interruption to the stream of life, so far as respects the races—if not the generic types—which for magnitude is quite in consonance with the wide revolution above adverted to in the physical geography of the Appalachian ocean and its bordering lands. This palæontological break is indeed only surpassed, as respects its grandeur, by one or two others in the whole succession of the epochs of the destruction and repeopling of the Palæozoic waters. Towards what quarter we are to seek for the maximum disturbance of the crust which produced the transition from the Auroral to the Matinal worlds, it is difficult, with the data hitherto collected, to determine; but there exist strong indications that it was towards the N.E. angle of the Appalachian sea. In more than one locality in that direction—namely, in places on Lake Champlain and in Canada—the Matinal or Trenton limestone seems to rest unconformably upon upturned and dislocated Auroral and Primal rocks, a condition of discontinuity not met with anywhere to the W. or S.W.

DEPOSITIONS AND DISTURBANCES OF THE MATINAL PERIOD.

Three successive sedimentary conditions appear to have prevailed in the Appalachian basin during the long Matinal ages. First, a state favourable to the deposition of an alternation of rather pure carbonate of lime and blue mud or clay, and to the existence of multitudes of marine species, in myriads of individuals of all grades, from corals up to trilobites. Secondly, a condition depositing nothing but a dark-blue carbonaceous mud, inhabited by a few delicately-constructed molluscs and small trilobites. Thirdly, a wholly different order of things, precipitating, through a long period, an alternation of deposits of sandy clay and clayey sand, crowded, where the waters were more calcareous, with marine creatures of very similar types to those that had frequented the two preceding deposits. Upon the first of these it is hardly necessary to speculate, after what has been already said. The age of the Matinal (Trenton) limestone was, throughout the Appalachian basin, one of extreme general tranquillity of the crust, of moderate depth, and only slight turbidity in the waters, and of climatal and other relations evidently conducive to a redundant harvest of living forms. The carbonaceous matter diffused in the blacker layers of the Matinal limestone and its shales, is attributed by some geologists to the carbon constituent of innumerable organic beings, of a soft fleshy structure, that possessed no shells or stony parts, and could leave no other vestige of their ever having lived.

Matinal Black Slate.—The transition from the formation of this very fossiliferous limestone to that of the bluish-black carbonaceous Matinal slate, was, throughout most portions of the basin now accessible to study, somewhat abrupt; though, as we have seen, it was extremely gradual in one part of their S.E. outcrop, or in the N. section of the great valley of Virginia. There, there is such an intermingling of the materials, and even the fossils of the two strata, that a division of the blended mass is difficult, if not impossible. But throughout Pennsylvania, and in all the country N. and N.W. of it, wherever both formations appear, their line of separation is a somewhat crisp one. It is evident from this, that over most of the watery floor there occurred almost simultaneously some great physical change, banishing the conditions favourable for the deposition or secretion of carbonate of lime, and permitting the introduction and tranquil precipitation of a dark carbonaceous sandy clay, or fine gritty blue mud. With this change there arose an almost entire destruction of the more than one hundred and eighty-eight species inhabiting the limestone sea, only two of these, so far as is yet known, surviving to flourish in the succeeding period of the dark muddy sediment which has hitherto revealed only eight races, to replace the more than one hundred and eighty-six exterminated. The age producing this Matinal black slate was therefore one manifestly very inimical to organic life. The deposit does not show itself at all, we believe, in the N.W. and W. outcrops of the other Matinal groups.

Matinal Shales.—Respecting the physical conditions concerned in the washing into the Appalachian sea of the deep and widespread accumulation of argillaceous matter and fine sand, which form, by their consolidation, the remarkable formation of the Matinal shales, we have to notice, as chiefly suggestive, the following circumstances: the deposit is thickest and most arenaceous along the great Appalachian valley, or at its S.E. outcrops, and particularly, it would seem, towards the N.E., or in Pennsylvania, New Jersey, and New York; and there it encloses, towards its upper limit, thick beds of coarse grey pebbly sandstone, and even of conglomerate. Along the N. and W. borders of the basin, the mass is much thinner, and of finer composition. It is obvious, therefore, that the materials were swept in mainly, or at least in greatest abundance, from the N.E. This view receives corroboration from another fact, previously given, that from a Northern district in Virginia, south-westward, and likewise throughout all its W. and N.W. outcrops, the formation loses its exclusively shore character, and becomes greatly more marine in its type, intercalating among its shales numerous thin plates of very fossiliferous limestone, until, in South-western Virginia, the lower half of it, and in Ohio and Wisconsin the whole mass, is as much a limestone as a shale. Combining these and other facts, we are impelled to infer, that while the Matinal waters were gradually receiving widely-strewn sediments of clay from the E., their S. and W. portions were less turbid, and were precipitating, between each incursion of the mud, their deposits of the carbonate of lime in pulpy sheets, that were teeming with creatures inhabiting its bed and floating in its waves. The steady, gradual change of composition in this great stratum, from its E. to its W. outcrops, is as remarkable as the opposite fact of constancy of type maintained by the two other groups, the limestone and black slate of the Matinal series, or, still more signally, by the Primal white sandstone.

The Galena Limestone.—This lead-bearing limestone of Wisconsin and Illinois, superior in position to the Matinal argillaceous limestone, and inferior to the Matinal shales, is evidently nearly upon the horizon of the Matinal black slate; but whether it was produced in the same age with that deposit, or in that next before it, or, again, in that next after it, we are without the means, for the present at least, of ascertaining, since the black slate and it nowhere occur in the same districts, nor even approach each other by a wide geographical interval. It is obvious, however, that at some period between the close of the calcareous limestone deposit and the beginning of that of the Matinal shale, while a part, at least, of the matter of the black slate was collecting, this galena limestone was in progress, imbedding its peculiar organisms. It pertained to some then existing condition of the physical geography of the N.W. side of the Appalachian basin, favourable to the production of a copious amount of carbonate of lime, for the formation is of considerable thickness under its fullest development. The very marked transition between the Matinal argillaceous limestone and this lead-bearing rock, in regard to their organic remains, strongly intimates that some important physical change occurred in the interval. Not improbably there was a depression of the bed of the sea. The general condition of the Appalachian sea during the Matinal period would appear to have been, considerable depth in the earlier ages, while the Matinal limestone was in progress; then comparative shallowness at the forming of the Matinal black slate; and finally, oscillations during the reception of the Matinal shales and sandstones.

STUPENDOUS CRUST-MOVEMENT AND REVOLUTION IN THE EARTH'S INHABITANTS AT THE CLOSE OF THE MATINAL PERIOD.

The relations of the Matinal series to the overlying sedimentary strata throughout the hitherto explored portions of the Appalachian basin, plainly show that all this portion of the earth's crust experienced a prodigious movement at the close of the Matinal period. This agitation of the floor of the sea, which had just received the materials of the Matinal shales, appears to have been everywhere attended by an extensive displacement of its level, accompanied, in some districts, by undulation, amounting even to a close plication or corrugation of its sediments, and, in some districts, to a lifting up of wide areas above the general sea-level into dry land. The proofs of this revolution—the most momentous, as it affected the physical geography and the organic inhabitants of the ancient North-American waters—have been set forth by me in a communication to the British Association, on the Correlation of the North American and British Palæozoic Strata, read at a meeting of that body in Cheltenham in 1856,* and the reader is referred to that essay for a full discussion of the subject; but the present seems a fit occasion for presenting an outline of the chief facts adduced.

From Gaspé, on the Gulf of St Lawrence, S.W. to the River Hudson, wherever the Matinal rocks appear in contact with any of the superposed formations, the former are either highly inclined and folded, or give evidence of disturbance and partial metamorphism, while the overlying strata display much less displacement and alteration. Within this range of 800 miles, sometimes the Oneida conglomerate, or lowest member of the Levant series—sometimes the Niagara or Scalent series—rests directly on the upturned Matinal. In the one case, the middle Palæozoic rocks repose upon the older unconformably, without a lapsus of any of the formations; but in the other case, the unconformity is accompanied by a wide hiatus in the series of strata. The latter condition was discovered by me near the city of Hudson in 1837, and was referred to in my Second Annual Report on the Geology of Pennsylvania, as proving the magnitude of the disturbance which terminated the formation of the Matinal shale. The locality where the unconformity was detected is Becraft's Mount, where the Lower Helderberg or Pre-meridian rocks are seen in horizontal stratification in the hill; while the Hudson River slates around its base are steeply inclined and contorted, from a movement previous to the deposition of the shales and limestones upon them.

Another locality, near the Hudson Valley, is the end of the Shawangunk Mountain. In this vicinity we may find instances of a physical unconformity of the Levant rocks upon the Matinal, and instances of a similar unconformity of still higher strata upon the same.

The cut here presented (Fig. 586) is a picture, taken on the spot, of the mode of contact of the Pre-meridian or Lower Helderberg limestone and the Matinal strata, as seen by us in 1842 at Hasbruck's Quarry. Here the attitude of the strata is such as to imply—first, an uptilting of the Matinal rocks into a steep inclination; secondly, a submersion of the uplifted surface to receive the deposition of the Pre-meridian limestone horizontally upon the edges of the Matinal slate, after these latter had remained above the water long enough for three great formations—the Levant, Surgent, and Scalent—to have taken place elsewhere; and, thirdly, another elevation imparting a steep dip to the horizontally-formed Pre-meridian limestone. We have the authority of Sir William Logan, in his Annual Reports of the Geological Survey of Canada, for stating "that in the E. division of the Palæozoic basin—that is to say, the portion S.E. of the St Lawrence—there are evidences of a want of conformity between the Upper and Lower Silurian formations." While such is the general state of things throughout the Appalachian chain N.E. of the Hudson, there exist, not improbably, districts within or beyond this belt where the sequence of the Palæozoic formations is full, and was not disturbed by any important physical movement at the close of the Matinal period, or the epoch which separated the middle from the older Palæozoic ages. One such district would seem to be the Island of Anticosta, where, it is alleged by the Canadian geologists, the Lower and Middle Palæozoic rocks exhibit not only an absence of all sign of physical disturbance at their passage, but display a remarkable commingling of their organic remains, proving an equally striking absence of any great disturbance in the conditions of life. Notwithstanding this exceptional instance, it would appear, from the Reports of the Geological Survey of Canada, that the Middle Palæozoic formations (the Upper Silurian of Murchison) repose very extensively in discordant stratification upon the Matinal or Hudson River rocks of Quebec and Sillery. In some quarters, this break in the sequence of deposits consists in the omission of one, and, in others, of more than one, formation, implying an uprising into dry land, and subsequent re-immersion of the bed of the Palæozoic ocean. There is evidence that this uplifting of the sea-bed extended as far S. as the W. side of the Hudson, and nearly as far W. as Oneida Lake.

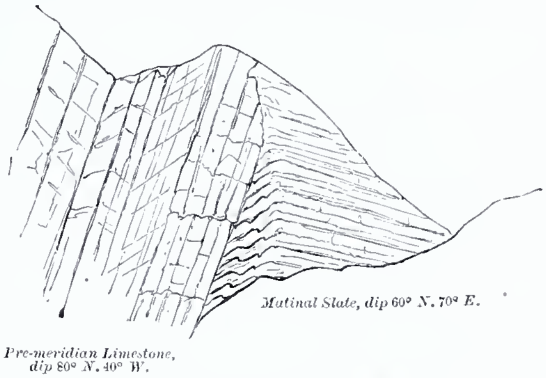

Matinal Slate, dip 60° N. 70° E.
Pre-meridian Limestone, dip 80° N. 40° W.

Fig. 586.—Hasbruck's Quarry, Rondout, showing unconformity of Pre-meridian upon Matinal strata.

This latter statement is confirmed by the fact that there is an omission of one or more of the formations at the base of the Middle Palæozoic series discernible throughout a winding line of outcrop, stretching from the Rondout River up the W. side of the Hudson River, and thence N.W. and W. by the base of the Helderberg Mountain, along the S. side of the valley of the Mohawk. From Rondout to Schoharie, the two lowest of the four Silurian formations are wholly wanting, causing the upper beds of the Scalent or Niagara group, and frequently even the lower layers of the Pre-meridian or Lower Helderberg group—the uppermost of all the Silurians—to lie in discordant contact upon the Matinal slates, or highest of the Cambrian equivalents. The undulations of the Matinal floor appear not to extend very far W. of the Hudson; for, as we ascend the Mohawk Valley, the higher series of rocks becomes parallel with the lower at their plane of contact. Only when we approach Oneida Lake does the conglomerate of the Levant series begin to take its intermediate place in the succession of strata, filling the gap between the two systems. But even it displays, over a wide tract to the W. of its E. margin, traces of the violence of the crust-movements of the period; for it is largely composed of fragmentary particles of the Primal, Auroral, and Matinal rocks, uplifted and eroded by the commotions which gave birth to it.

---

* Report of Twenty-Sixth Meeting of British Association, held at Cheltenham.

Along the entire S.E. margin, or mountain front, of the Appalachian basin, between the Hudson and its S. border in Alabama, the close of the Matinal period exhibits indications of a great and violent change in the state of the waters, implying a commensurate degree of action in the ocean's floor and ancient shores. Although there is no hiatus in the series of formations, nor any want of parallelism between the upper and lower groups, yet there prevails so abrupt or sharp a plain of separation—such a striking change in the sedimentary materials—such proofs of the upper rock, the Levant conglomerate, having been formed out of the wreck of the Matinal and other lower strata—and such indications that the shore-line had undergone an extensive shift in its position, that the evidence of a violent movement of the crust, or change in the level of the sea-bed, is almost as conclusive for this half of the Appalachian zone as for the portion N.E. of the Hudson Valley.

Turning next to the N. outcrop of the Matinal deposits, with a view to the question, whether the disturbance which marked the close of the Matinal period, in the line of the Appalachian chain, extended along this border of the basin, we find that the sequence of the formations remains complete only for a short distance W. of Oneida County—namely, to the E. end of Lake Ontario—and that the break prevails again from Lake Ontario westward to the Missouri River, and generally throughout the wide plain W. of the Appalachian Mountains. Indeed, the whole of the Levant series is not present anywhere W. of Oneida County, but only the Medina sandstone or upper member. This rock, serving but partially to fill the gap, extends through New York to the head of Lake Ontario, and thence, thinning down to the Manitoulin Islands of Lake Huron, it vanishes. The blank thus left by it reaches from Lake Huron to the W. boundary of Iowa.

Tracing the next higher group, the Surgent or Clinton formation, along this border of the basin, from where it takes its station in the series at the foot of the Helderberg Mountain near Schoharie we follow it through New York, to the Niagara River, and through Canada to the Manitoulin Islands, and doubtfully beyond these to the E. end of Green Bay, where there is no longer any vestige of it. The whole deposit is very thin between the Niagara River and the Manitoulins. Though a few fossils of the formation occur among Scalent (Niagara) fossils in Wisconsin, no independent Surgent formation seems to exist there; on the contrary, there is an omission of two entire formations above the Matinal shales all the way from the peninsula, dividing lakes Michigan and Superior, to the neighbourhood of the Missouri River, where the cretaceous deposits of Nebraska overlap and conceal all the older Palæozoic rocks in their prolongation West.

Still directing our attention to the N. border of the basin, bounded by the Matinal outcrop, we observe that the Scalent or Niagara series—the third great Middle Palæozoic formation—assumes its place in the break we have been describing, somewhat farther W. than the Surgent deposit, but presents a much broader outcrop and a far greater development. This group, almost wanting in the Appalachian chain to the S.W. of the Hudson, and very thin in the E. part of New York, becomes, in the W. part of that State, a stratum of much magnitude; and it retains this expansion, and a commensurate richness in its organic remains, all the way to its W. limit, near the Missouri River. From the region of Lake Michigan, to its disappearance beneath the cretaceous strata of Nebraska, it was the first Silurian or Middle Palæozoic formation precipitated on the floor of the Appalachian sea, then established on the previously uplifted and re-submerged strata of the Matinal series.

Reviewing the phenomena presented by this N. outcrop of the earlier Middle Palæozoic strata, we find that they indicate, as among the most important revolutions of the physical geography of their periods, first, at the close of the Matinal age, a tremendous agitation of the bed of the Palæozoic sea, resulting in the upheaval and draining of its sediments throughout several wide districts, and a very general shoaling of the remaining portions. There next arose a local paroxysmal movement of depression in the Appalachian chain S.W. of the Hudson, accompanied by deposition of the Levant or Oneida conglomerate within its narrow area, but characterised elsewhere as a gradual and progressive sinking under of the upraised sea-bed, throughout wider and wider limits, during the later Levant (Medina) and the Surgent (Clinton) periods, until the waters, in the next or Scalent (Niagara) period, resumed almost their ancient extension over their recovered floor. During the first period of this re-subsidence the sea occupied only a long narrow trough, parallel with the Appalachian Mountains, spreading no more than 100 or 200 miles W. from the zone they subsequently occupied. In the next or later Levant (Medina) age, the waters had encroached W. as far as Lake Huron, but were extremely shallow; and in the succeeding or Surgent (Clinton) period, growing deeper, and supporting a greater multitude of inhabitants, they diffused themselves to a limit W. of what is now Lake Michigan. But it was only in the next long age—that of the Scalent (Niagara) formations—that this second-time-created Palæozoic sea recovered all its earlier wide dominion, and spread its waves from where the Appalachian Mountains afterwards uprose upon its borders, and cast it off as far as a distant Western shore, perhaps to be yet discovered, in the region of the Rocky Mountains.

The great crust-movement, denoted by the break in the stratification at the upper limit of the Matinal series, is proved to have extended to the interior of the Palæozoic basin. It is clearly shown in the geological phenomena of the wide anticlinal zone which ranges through Western Ohio, and Middle Kentucky, and Tennessee, approximately parallel with the Appalachian chain. In two districts within this broad flat wave of the strata, the Lower Palæozoic rocks are lifted to the day, and made visible by denudation. In one of these tracts, having Cincinnati for its centre, the Matinal beds, forming a large, elliptical, dome-shaped outcrop, are overlaid by the Scalent or Niagara group, containing, amid its own appropriate fossils, two or three species distinctive of the Surgent or Clinton, though no true Surgent sediments are recognisable. A similar omission of the lowest of the Middle Palæozoic formations occurs around the anticlinal area of Middle Tennessee, along the E. side of which there is neither Levant, Surgent, Scalent, nor Pre-meridian deposit—in other words, no true Silurian formation whatsoever intervening between the Matinal, or uppermost of the older Palæozoic or Cambrian formations, and the Cadent black-slate, the lowest W. representative of the European Devonian strata. But along the N. and W. margin of this tract there does occur a thin layer of Scalent (Niagara) limestone, containing one or two Clinton and Lower Helderberg fossils; and this is the only deposit of a middle Palæozoic age which appears in the wide break between the lower and upper masses along this W. anticlinal uplift of the formations.

The same inferences are deducible from the absence of the earlier Middle Palæozoic formations in this zone as have been already drawn from their non-existence along the Northern side of the basin; namely, that the sea-bottom was upraised into dry land over all this area at the close of the Matinal period, and not fully submerged again until the age of the Scalent or Niagara limestone had arrived.

A still more extensive area of elevation of the Matinal sea-bed is discernible to the W. of the zone just described, in a long chain of exposures of the older rocks, stretching from Lake Superior by the valley of the Mississippi through Southern Missouri and Northern Arkansas, and the Washita Hills, to the igneous axis of the Rio Colorado in Texas. In this long chain of partially independent axes of elevation, observing the same N.E. and S.W. trend which characterises the Appalachians, the undulations are fewer, more depressed, and less continuous than those of that mountain system. The largest areas of the older rocks within this zone are that of Northern and Middle Wisconsin, and that of Eastern Missouri, in both of which the undulations of the crust appear to observe a general N.E. and S.W. trend, or to be in parallelism with those of the Appalachian chain. Other flexures affect the carboniferous strata of the coal-fields E. and W. of the Mississippi; but those which are of a later origin appear to possess in the main a N.W. and S.E. direction, or to conform rather to the lines of elevations and undulations of the Rocky Mountains.

The same great break or interruption in the series of the sedimentary formations, at the upper limit of the Lower Palæozoic strata, is visible around these several Western areas of elevation. In some districts, only a few of the lowest formations of the Middle Palæozoic series are wanting. In other tracts there is no trace of any true Silurian rock, and even the lower members of the Upper Palæozoic series—that is to say, the equivalents of some of the European Devonian—are also absent. Thus a very common case of superposition is that of the Vergent or Chemung formation, resting with a gentle inclination upon equally gently-dipping beds of the Auroral or Matinal series; in Missouri, most generally on the Auroral limestones. In not a few sections in Missouri, there is an almost perfect parallelism between the upper and lower formations, notwithstanding the omisson of several important formations of the middle period.

According to the geological survey of Dr Owen, and the later researches conducted by Professor Swallow, there is a wide irregular tract of the older Palæozoic rocks—Matinal and Auroral—extending along the Missouri River from Moniteau County to St Charles County, and Northward from the Missouri to Salt River of the Upper Mississippi; and the late investigations under Professor Swallow show that this area of the older Palæozoics, or so-called lower Silurian rocks, embraces nearly all the counties of the State south of the Missouri River, excepting a Western belt occupied by the carboniferous limestone and Coal-measures. His map and sections prove, moreover, that all along the irregular N.W. border of this ancient area, the Vergent (Middle Devonian) strata repose with parallelism, but with interruption of sequence, upon either the Matinal or Auroral limestones. There is reason to believe that a similar structural condition prevails still farther to the S.W. In many localities the Vergent formation—called in Missouri the Choteau Limestone—is a thin and obscure stratum, and there the carboniferous limestone appears to overlie the limestones of the older Palæozoic series; but the true extent of the hiatus is that of all the middle and upper Palæozoic formations from the bottom of the Levant to the base of the Vergent.

From these statements it is obvious that, throughout at least a large area of this Western anticlinal zone, the sea-bottom was elevated into dry land at the end of the Matinal period, as it was so extensively in other quarters; but it appears to have remained thus uncovered for a longer interval, or during the lapse of a greater number of formations, than in the tracts farther E. In some districts of the Appalachian chain the uplifting of the Matinal sea-bed was followed immediately by its re-immersion; W. of the mountains, in the district of Lake Ontario, the re-entering of the waters for the deposition of new sediments did not begin till the latter part of the Levant period (Medina). Still farther W. of the chain, or beyond Lake Huron, and in the wide uplift of Ohio and Middle Tennessee, the re-immersion did not take place till the Scalent or Niagara age, and then only partially; and here, in the farthest exposed tract of all in the meridian of Missouri, the return of the waters was postponed until the period of the Vergent sediments, or the middle epoch of the Devonian ages. We may regard this Middle Palæozoic or Silurian sea as a wide mediterranean, covering those portions of the crust which are now occupied by the Northern, Middle, and North-western Atlantic States, gradually shifting its borders and encroaching Westward for the production of successive formations; but it was by no means coextensive with the broader ocean of the three earlier series of formations, the upheaval of whose extensive bed at the close of the Matinal ages conferred upon it its own more restricted shores.

PALÆONTOLOGICAL BREAK AT THE END OF THE MATINAL PERIOD.

By far the most complete interruption in the life of the Palæozoic waters, within the limits of the Appalachian sea, was that which occurred at the close of the Matinal period. It amounted apparently to the extinction of all the organised existences, both plants and animals, of which any relics have been preserved to us. Out of more than 400 species, now known as entombed in the lower Palæozoic rocks of the United States, not more than two or three—and of these there is a doubt—survived the convulsions which closed the Matinal period, and ushered in the conditions which witnessed the deposition of the Middle Palæozoic formations. Every one of the few specimens of the two or three dubious species alluded to were found in so worn and injured a state as to suggest that they had been washed out of the Matinal strata, and may not have lived in any later waters. With the exception of these, every fossil preserved in the deposits overlying the Matinal are specifically distinct from their predecessors, and, according to Mr Hall, those from the Middle Palæozoic rocks, or from the Medina, Clinton, Niagara, Coralline, and Onondaga salt groups of New York, numbered in 1853 nearly 350, to which we may add more than 200 additional species from the lower Helderberg or Pre-meridian series, making in all about 550 Silurian forms unlike any characteristic of the strata below the great break.

DEPOSITION AND DISTURBANCES OF THE LEVANT PERIOD.

The conditions under which the three members of the Levant series were deposited, were evidently peculiar for each. The Levant grey sandstone (Oneida conglomerate of New York), more or less pebbly in its lower beds, and growing less and less coarse as we trace it W. across the Appalachian chain, appears to have been deposited upon the newly-established bed of the ocean by the currents produced by the last of the train of agitations which had just previously terminated the Matinal deposits, and shifted the relations of the waters to the land. We have already inferred that the currents which strewed its materials moved from the E. and N.E. This formation, more than 500 feet thick in some parts of the Appalachian chain, dwindles to nothing under the great coal-basin W. of the mountains, indicating that the waters did not cover the great anticlinal zone of the older Palæozoic rocks of Ohio and Middle Tennessee.

The Levant red sandstone (Medina red shale of New York) fills an area lying somewhat W. of that of the grey sandstone under it. Its E. margin does not reach the border of the great Appalachian valley, where the other is in full force. Expanding to a thickness of 1000 feet before it dives under the great coal-field, it yet fails to reach the anticlinal of Ohio and Tennessee; and its true W. limit is therefore unknown, except along the N. border of the basin, where, as already hinted, it stretches almost as far W. as the Straits of Mackinac. The epoch of this deposit was obviously marked by much greater tranquillity in the waters than those of the strata above and beneath it. In Western New York, and other districts, where the conditions attending its deposition were comparatively quiet, its materials are chiefly those of a finely-comminuted red marl or calcareous red clay, and it contains a few organic remains; but in Pennsylvania, and throughout the Appalachian chain, it is a coarser and more sandy rock, and is almost wholly destitute of fossils. It is not easy to say from which quarter the supply of this sheet of sediment was derived, though the indications are that the source was the N.E.

The Levant white sandstone, also a part of the Medina group of New York, consisting of white sandstones and olive-coloured and reddish slates in complex alternation, though a conspicuous member of the series in the Appalachian Mountains, evidently ceases, like the others, under the great coal-field. Along the N. side of the basin it reaches W. beyond Lake Ontario, becoming, however, very thin. Its upper layers contain in New York, where its chief sandstone member is known as the Medina Sandstone, several characteristic fossils. Some of these, particularly the marine plants, characterise the rock throughout its whole range from Pennsylvania to the S. border of Tennessee. In the Appalachians, the dominant member of this group is a fine-grained yellowish-white sandstone, in some localities almost snowy white. Neither this rock, which belongs to the lower half of the formation, nor the slates and grey sandstones above it, appear to extend as far to the W. in the region of the lakes as the Levant red shale beneath it.

A striking feature of all these strata forming the Levant series, is their general poverty in organic remains. It would seem as if the ocean had not resumed, during their deposition, a state sufficiently favourable for living beings, after the excessive turmoil it had undergone at the close of the preceding Matinal period. Possibly the newly-established climatal conditions of the waters were unfavourable to life; possibly the Levant sea of the Appalachian region was too much insulated from the general ocean of the globe for the introduction by colonisation of the species already created and flourishing in other quarters; possibly time enough had not yet elapsed, after the almost total extinction which marine life had undergone, for the repeopling of this insulated sea.

The disturbances of the crust, and the consequent revolutions of the physical geography in the Levant period, though important, were manifestly of less magnitude than some of those of an earlier date; they were, however, sufficiently great to produce entire alterations in the nature of the sediments, and essential changes in the limits to which these sediments were wafted: we are entitled to infer, indeed, from the superior Westward distribution of the later over the earlier members of this series, that, as the deposition proceeded, the commotions of the crust resulted in a constantly-increasing extension of the Levant waters in that direction, or, in other words, a progressive subsidence of the previously-uplifted Matinal shores.

DEPOSITION AND DISTURBANCES OF THE SURGENT SERIES.

The physical circumstances attending the sedimentation of the very complicated group of deposits we have called the Surgent series, were manifestly very fluctuating. The seven formations or sub-groups of beds composing it were deposited in the region of the Appalachian chain during a long period of alternating conditions of the waters; the Surgent lower slate, Surgent upper slate, Surgent lower shale, and Surgent upper shale, being all precipitated from gently-moving water, which accumulated them towards the N.W. side of the mountain-zone; the Surgent red shale accumulating most to the S.E., and the two sandstones, the Surgent Iron-sandstone and Surgent Ore-sandstone, by swifter currents dispersing their materials widely, but laying them down more irregularly.

Though none of the deposits of the Surgent series reached the anticlinal uplift of Ohio and Middle Tennessee, they seem to have gained the meridian of Lake Huron, where probably the waters of the period possessed a wider Westward diffusion.

The statement already made, that the next later formation, the Scalent (Niagara) limestone, bordering the dome-shaped Matinal rocks in Southern Ohio, though not underlaid by any Levant sediments, contains two or three Levant fossils mingled with its own proper species, suggests as a probability that the Levant waters could not have been far distant at the beginning of the Scalent formation, though it must be confessed we are not in a position to argue critically from phenomena of this sort, until we know more than we do concerning the rate at which species extend or colonise themselves from one geographical habitat to another.

The Surgent period seems to have been one marked by no violent commotion within the Appalachian area. The series is, indeed, singularly destitute of deposits implying any violent action of the waters, being, with the exception of its two sandstones, composed almost entirely of finely-comminuted material, such as denote only very quiescent currents. It appears to have been ushered in most gently, for the transition from the antecedent Levant slates to the slates of this epoch is almost imperceptible. It will appear presently that the passage from the deposition of the Surgent rocks to that of the succeeding Scalent formation, was, if possible, even more gradual, being attended by simply a gradual change in the sedimentation, and a slow successive dying-out of certain forms of life, with a quiet introduction of new forms to replace them.

DEPOSITION AND DISTURBANCES OF THE SCALENT SERIES.

The Scalent (Niagara) deposits, consisting of variegated marls and grey marls surmounted by limestone, exhibit a more decidedly Western development than the two preceding groups. The variegated and grey marls, thick, but not very persistent, in Pennsylvania, follow the Appalachian chain far to the S.W. in Virginia, and their limestone (the water-lime of New York) is also very generally met with; but the Scalent limestone (Niagara) is hardly to be met with in the mountains S.W. of its N. outcrop in New York. On the other hand, the marl-groups cease ere we reach the uplift of the strata in Middle Tennessee, while both they and the Scalent limestone spread far to the W. in more Northern latitudes. It has been already stated that the limestone (Niagara) is imperfectly developed around the Matinal areas of Ohio and Middle Tennessee; indeed, it there appears to constitute the first independent formation deposited after the elevation of the older Palæozoic rocks. It appears to be present too, though thin, in some localities in contact with these older formations in Missouri. But along the N. border of the basin, this limestone, and the shale which accompanies it, stretches continuously, from the Helderberg Mountain in New York, the whole way past the Lawrentian lakes and across the Mississippi nearly to the Missouri, where it is overlapped and hid under the cretaceous basin of Nebraska. From these statements it is obvious that the waters of the later ages of the Scalent period, charged with their clayey sediments, wafted these in greatest abundance to the zone which afterwards became the Appalachian chain, not conveying them to the region of Middle Tennessee, whereas those of the earlier or limestone age precipitated their calcareous matter far more widely towards the W., and in greatest abundance towards the N., or rather the N.W.

The finely-comminuted condition of all the deposits of this series, and the great profusion of organic remains entombed in its once pulpy sediments of clay and carbonate of lime, and the wide uniform sheets into which these sediments were dispersed, all go to prove that the period was one of extremely quiet and uninterrupted aqueous and vital action. We have seen already that the passage strata between the base of this series and the top of the Surgent series subjacent to it, betoken an extremely gentle transition from the one formation to the other, there being, indeed, no sharp line of demarcation to separate either the mineral materials or the organic forms of the red marls of the Surgent group from the variegated and grey marls of the Scalent series before us. We shall hereafter witness a similar gentleness of gradation, implying a similar absence of disturbance at the upper limit of the series, or that which divides it from the overlying shales and limestone of the Pre-meridian or lower Helderberg group.

It is not easy to speculate as to the features of the physical geography, and the aqueous conditions which attended the precipitation of the Niagara or upper Scalent limestone. It is easy enough to account for the clayey sediments of the overlying saliferous shales, as we may readily conceive, from what has been sketched above, that the Appalachian sea of the period must have been bordered by very wide tracts of the yet imperfectly-consolidated clayey strata, those of the Primal and Matinal slates and shales converted into dry land at the period of crust-disturbance which preceded the Middle Palæozoic or Silurian formations. The repleteness of the waters in marine organisms, mollusca, corals, &c., adapted to the secretion of carbonate of lime, suggests that they must have been charged with an abundance of this substance; and we may imagine a ready source for it in the broad tracts of Auroral and Matinal limestone sediments raised into dry land at the close of the Matinal period, the atmospheric waters dissolving this mineral substance, and conveying it to the sea. Perhaps the view of the origin of the limestone most consistent with sound chemical and zoological science is this, that the shore or margin of the Appalachian sea of the time, and all its shoals and islands, were widely fringed with a growth of lime-secreting corals and broad beds or colonies of shell-fish; and that large quantities of carbonate of lime and other constituents of the limestone were poured in among these stone-producing animals, by streams flowing off from the wide upraised plains of the older Palæozoic limestone. It is difficult to conceive that the whole of this broad fossiliferous stratum, abounding though it does in stony corals, was a coral reef in the true sense of that term, for the stratum is too wide, being, in fact, coextensive with almost the entire Northern half of the Palæozoic basin W. of the Appalachian chain: the composition of the rock suggests, moreover, an influx of too much material from the land to be compatible with the simple reef hypothesis.

DEPOSITION AND DISTURBANCES OF THE PRE-MERIDIAN SERIES.

This latest or uppermost representative of the European Silurian rocks maintains itself throughout the Appalachian chain, with a thickness fluctuating from zero to 250 feet, ranging from New York to the Southern States; but it seems to extend to only a comparatively limited distance N.W. of the mountains. Its chief member, the Lower Helderberg limestone, does not reach Western New York, nor is it discernible in the anticlinal belt of Middle Tennessee, where it should appear if it had been deposited so far to the W. It was evidently formed in a basin occupying the existing site of the S. half of the Appalachian chain, having its S.E. margin near the Appalachian valley, towards which the deposit thins to nothing, and its W. limit E. of Lake Ontario and the upraised Matinal areas of Ohio and Middle Tennessee. This slender shallow arm or strait of the Silurian sea was evidently, especially towards the N., of narrower E. and W. dimensions than the area occupied by the waters in the preceding periods. It was bounded, no doubt, both S.E. and N.W., by the uplifted tracts of the older Palæozoic deposits; and we may imagine that the restriction which the basin underwent in the Pre-meridian period was due to a moderate elevation of the crust in the previously upraised anticlinal zone, traceable from the W. end of Lake Erie to Western Ohio, and Middle Kentucky and Tennessee. The coming in of this formation seems not to have been marked by any great paroxysmal movement, though the transition between its organic remains and those of the preceding deposits shows a great revolution in the conditions affecting marine life, this formation being very prolific in organic remains, not less than 200 species of which have been discovered in New York. The close of the formation betokens a very general disturbance of the waters, cutting off nearly all the living inhabitants, suspending the calcareous deposit, and strewing the shifted sea-bed with coarse silicious sand, to the production of a new formation. To this we next proceed.

DEPOSITION AND DISTURBANCES OF THE MERIDIAN SERIES.

This well-characterised sandstone, deemed by palæontologists to be the lowest or oldest representative of the European Devonian formations, is almost as much restricted as the Pre-meridian limestone upon which it reposes, to the Appalachian chain, and the zone immediately W. of it. It does not reach the anticlinal uplift of the strata W. of the great coal-field, but merely spreads itself in a very attenuated stratum as far along its N. outcrop as Western New York. To the S.W. it occurs in the mountains at least as far as Eastern Tennessee. Its greatest thickness is about 200 feet, but it fluctuates much in size; and among the E. outcrops of the strata in the Appalachians, it is sometimes wholly wanting. From these and other circumstances we may infer that this formation was deposited in nearly the same basin or trough of the waters as that which received the Pre-meridian limestone, after a disturbance had taken place, however, in the sea-bottom, and a corresponding change in their shores, especially their N. ones, and after an equally momentous change had arisen in the state of the waters themselves, which were previously quiescent and charged with calcareous matter, but had now become agitated with currents, and turbid with a profusion of floating sand.

The more than 200 species of creatures living in the Pre-meridian sea were all cut off by the changes which ushered in this deposit, and a few new organisms of peculiar type assumed their place. The uncongenial nature of the sediment, and probably the unsteady condition of the medium by which they lived, prevented these from being either numerous in species or populous in individuals. A still greater revolution in the physical geography than that which brought in this Meridian deposit, wholly subverted it, and gave place to a new condition of the sea, productive of a calcareous sediment of altogether wider dimensions.

DEPOSITION AND DISTURBANCES OF THE POST-MERIDIAN SERIES.

The Post-meridian deposits, called in New York the Upper Helderberg group, have a very restricted E. outcrop, their range along the Appalachians extending no farther than from the base of the Catskill Mountain to the Lehigh River; but they have a very extended N. one, stretching from the Hudson westward to Lake Erie, and thence N.W. to Lake Michigan; Southward to Middle Tennessee, and Westward through Northern Ohio, Indiana, and Illinois, and thence through Northern Iowa even to the Missouri River. Though thin towards the E., the formation acquires in the W. a maximum thickness of 350 feet. It encompasses the dome-shaped anticlinal area of the older Palæozoic rocks in Ohio and Kentucky, and just reaches the N. verge of that of Middle Tennessee. Farther W., its most Southern visible outcrops are in Eastern Missouri, where its maximum thickness does not exceed 75 feet.

This widely-distributed calcareous formation, distinguishable from both the underlying and overlying deposits by sixty or more known species of interesting fossils, appears to have been formed in a wide basin which had its S.E. shore under the great Appalachian coal-field, and its N. one nearly coincident with the Lawrentian lakes as far as the Straits of Mackinac. We may presume that its materials were derived from the same sources which furnished those of the great Scalent (Niagara) limestone, upon which, in the Western States, it very generally reposes. The branch of the Palæozoic sea, or wide marine trough in which this very fossiliferous limestone was collected, must have possessed very different limits and dissimilar configuration from those which were the receptacles of the two preceding deposits. Indeed, all the formations, from the Levant to the Meridian sediments inclusive, excepting the great Scalent (Niagara) limestone, were evidently accumulated in a sheet of water extending far, from N.E. to S.W., but comparatively narrow in an E. and W. direction; whereas this far broader formation was spread over a sea-bed, longest from E. to W., and of a N. and S. expansion equal to the length of the other.

A glance at the Geological Map of the United States enables one to discern, in this contrast between the boundaries of the Post-meridian limestone and those of the formations beneath it, the magnitude of the change in a distribution of land and water which must have occurred at the close of the Meridian period. It amounted probably to a submersion of the whole broad area which intervened between the anticlinal zone of Ohio and Middle Tennessee and the W. visible limits of the Palæozoic strata. So prodigious a revolution in the area of the waters, implies a very broad or diffused sinking of the lands upraised at the end of the Matinal and later epochs. The phenomena do not imply, however, that this subsidence of the crust was paroxysmal or very sudden; for though the base of the formation consists, especially Eastward, of argillaceous grits, indicative of some commotion in the yet shallow waters, the prevailing presence of a very pure limestone, with numerous organic remains of structures incompatible with a turbulent medium, intimates very plainly that the deposit took place during a protracted period of repose, ushered in by no convulsive heavings of the crust, but by a gentle and gradual depression of the surface. The termination of the deposit was effected, however, more abruptly, as will be better understood when we have passed in review the physical geography of the next succeeding or Cadent series.

Nearly 100 species of marine organic remains have been already recognised in this formation, and none of them are specifically identical with the forms recovered from the Meridian or yet older strata. Notwithstanding this insulation or exclusive character of its fossils, it is a curious fact that several of its forms resemble closely those of the upper Silurian rocks of Europe, especially the Ludlow strata of England. It would seem as if these Transatlantic species had somehow survived the convulsions which exterminated them in the European part of the Palæozoic ocean, in the end of the Ludlow or Silurian ages, to colonise the waters of the American branch of that sea in the later epoch of this Post-meridian period, which, by the aspect of all its other fossils, is of true Devonian and not Silurian date.

DEPOSITIONS AND DISTURBANCES OF THE CADENT SERIES.

The deposits of the Cadent series resemble none of the formations which preceded them, except the Matinal. Like these, they consist of fissile black carbonaceous slates, and of olive-coloured and bluish more or less sandy shales. They are also almost commensurate with that series in their geographical distribution, following the Appalachian chain from New York to East Tennessee, and extending from the Hudson River to an immense distance W. and N.W. through the continent. Towards the N.E. they appear to enclose the coal-field of New Brunswick. Judging from the composition and contents of the formation—which, it will be recollected, comprises three chief members, two bituminous black slates and an interposed shale—the circumstances under which these sediments were formed must have been peculiar. The Cadent older black slate, the lowest member of the series, reposing immediately upon the Post-meridian limestone, could hardly, from the nature of its materials and its fossils, have been a deep-sea or mid-sea deposit, but was apparently accumulated in very shallow water, over a vastly-expanded and very level plain. It contains, mingled with several species of decidedly marine mollusca, vestiges of a vegetation which appears to have been air-breathing or terrestrial; and it possesses, moreover, such an amount of bituminous matter, or, more truly, such a quantity of material yielding carburetted hydrogen gas, as to give us the impression that it was the accumulation of a very widely-spread sea-marsh or marine savannah. Early in the progress of this deposit, the surface upon which it was forming must have undergone a wide but gentle depression; for, intercalated low down in the black slate, there occurs a band of marine limestone and calcareous carbonate of iron, imbedding organic remains, which imply some depth of oceanic waters.

The second member of the series, the olive-coloured and blue shale, apparently owes its origin to a different physical geography. It seems to have been accumulated in deeper and less sluggish waters—to be the result, in fact, of wide-sweeping, steady currents, charged with argillaceous sediment, sometimes mingled with much sand, and replete with an exclusively marine life. Neither this middle member, nor the black slate supporting it, were spread very widely to the W. of the zone now occupied by the Appalachian chain.

The Cadent upper black slate, however, or a member of the series answering to this description, is very widely distributed, not only along the mountains, but as far W. as the E. verge of the great carboniferous basin of Indiana and Illinois. Indeed, upon the excellent authority of Sir John Richardson, a rock, identical with it or the Cadent lower black slate, occurs far in the interior of the continent, with an outcrop ranging in a N.W. direction through the British Territories, even to the Mackenzie River. Throughout the Appalachian chain and in Ohio, this upper black slate is almost the exact counterpart of the lower; indeed, so closely alike are they, even in their organic remains, that some doubt still exists as to which of them we should refer the black slate of the Western States. In Pennsylvania, this uppermost Cadent formation contains in some localities well-preserved remains of *Lepidodendron*, one of the well-known fossil plants deemed to be distinctive of the Palæozoic coal-measures, fragments of this vegetation abounding indeed between its laminæ. The deposit is, moreover, almost everywhere more or less bituminous, yielding petroleum on distillation, and emitting naturally not only this fluid, but much carburetted hydrogen or coal-gas. Notwithstanding the presence of a few marine or aquatic organisms, this feature seems to justify the hypothesis we have above ventured upon, in explanation of the similarly-constituted lower black slate of the same series. I deem it highly probable that the whole deposit was once the muddy floor of a broad sea-meadow or morass, occupied at times by the ocean tides, and sustaining, at least in its drier localities, an air-breathing or terrestrial vegetation, foreshadowing in its aspect and structure that of the coal-producing savannahs of the long-subsequent carboniferous ages.

It is evident, from this brief sketch of the conditions of deposition of the Cadent strata, that an entire revolution must have taken place in the physical geography of the Palæozoic sea at the close of the Pre-meridian period. It is not difficult to perceive that this change was connected with an extensive shallowing of the waters, and with an oscillation of the bed of the sea which twice brought it, at least over very wide tracts, almost into the condition of dry land. In this tendency to a shoaling up, or to a broad-diffused rising of the bed and shores of the Appalachian ocean, in the later Palæozoic times, we witness the beginning of that interesting train of oscillations of level which terminated in the great coal-formation, where the proofs of such a fluctuation are so conspicuous. As we proceed in our sketch of what is most significant among the phenomena of the later formations, we shall discover more and more abundant relics of terrestrial vegetable life, and constantly-accumulating evidences of this frequently-recurring oscillation with exposure to the atmosphere, of the ancient Devonian and Carboniferous shores, until we enter the coal strata themselves, where every coal-bed is a monument of a plane at the sea-level, supporting its rank vegetation partly in the water, partly in the air.

DEPOSITIONS AND DISTURBANCES OF THE VERGENT SERIES.

The state of things prevailing at the deposition of the Vergent series (Chemung group) would appear to be very different from those productive of the Cadent black slates, but somewhat analogous to the conditions which gave birth to the Cadent shales. In the Appalachian chain the formation comprises two members: a lower mass, composed of flagstones parted by blue shale, and abounding in the marine vegetation called Fucoides; and an upper mass, consisting of grey and olive-coloured shales and grey sandstones, replete in the shaly beds with marine mollusca, especially brachiopods. Under these types this series ranges from New York along the Appalachian chain to Tennessee, and W. through the S. side of New York to Lake Erie, and thence S.W., skirting the great Appalachian coal-field to the Tennessee River in Northern Alabama. From Middle Tennessee, where it encompasses the older formations in a narrow tortuous outcrop, it sweeps N. through Kentucky, and thence N.W. along the E. margin of the second great coal-field to Northern Illinois, where it thins out near the Desplaines River east of La Salle. The formation reappears on the W. side of the Illinois coal-field, and ranges in a slender irregular outcrop in a S.W. direction centrally across the State of Missouri, which it leaves at its S.W. corner to enter the Indian territory. At this its most Western outcrop the rock wears a very different type from that which it possesses anywhere E. of the Illinois coal-field. The lowest member is a lithographic limestone about 60 feet thick; the middle a blue shale and buff-coloured argillo-calcareous sandstone, containing but few fossils, except Fucoides or sea-weeds, and usually about 75 feet thick; and the highest member, a limestone, magnesian in its upper division, and 70 feet thick when at a maximum. Lithologically, the middle member is the only one which corresponds to the E. type of the deposit, and it is probable that the limestones which enclose it are independent sub-formations not elsewhere represented.

Taking a wide view of the Vergent series, one of the features which first arrests our attention is the amazing declension in thickness which the whole mass undergoes as it spreads from the Appalachian chain to Northern Illinois and Missouri, declining with a regular gradation from a diameter of nearly 5000 feet to one of 200 feet W. of the Mississippi, and thinning to nothing S.W. of Lake Michigan. This gradual declension of size is attended with a gradual reduction in the coarseness of the whole mass, and in the magnitude and frequency of the arenaceous beds—all circumstances which go to indicate that the E. and S.E. was the quarter whence the materials were derived. A confirmation of this view is to be found in the less littoral or more purely marine character of all divisions of the mass in its extreme W. outcrop in Missouri. One of the most surprising features of the formation is the aspect which it almost everywhere presents of shallowness in the depositing waters. One intimation of this is the constant abundance of certain types of marine vegetation, such as could hardly flourish in a deep sea ; another is the occasional presence of relics of a terrestrial flora, especially of *Lepidodendron*. But the most significant signs of all are the frequent occurrence of ripple-marks, and the *glazed* surfaces and lines of trickle, which imply extreme shallowness in the water, and occasional exposure of the forming sediments to the atmosphere.

It is obvious that the waters which received this formation, though not deep, were very widely distributed, spreading Westward even beyond the limits which they occupied in the preceding period, during the deposition of the Cadent sediments. I think we are entitled, from all the phenomena of the Vergent series, to conjecture that its sea-basin experienced, throughout at least its Eastern half, a gradual progressive subsidence of its bed, without any important paroxysmal oscillations during the accumulation of its sediments, and that the materials for these were swept in, under remarkably uniform conditions, during a great lapse of time. The beginning of the Vergent formation was not signalised by any vehement crust-disturbance, nor do we witness indications of any violent derangement of the floor of the sea at the close of the period, though in the W. portion of the area we behold a break in the succession of the strata, or a conformable interrupted sequence, of much importance, implying a quiet lifting-up of the sea-bed into dry land at this epoch. The proofs of this will appear under the next head.

DEPOSITIONS AND DISTURBANCES OF THE PONENT SERIES.

The Ponent series (Catskill Group of New York), the uppermost Red Shale and Sandstone formation, except the Umbral series, or middle member of the Carboniferous formations, would appear to be an exclusively Eastern or Appalachian deposit. It seems to attain its greatest bulk in Pennsylvania, where its thickness exceeds 5000 feet. It gradually declines in size toward the S.W., and even thins away in Eastern Tennessee. In a transverse direction it abates much more rapidly, growing thin under the Alleghany Mountain, and fining off to nothing before it reaches the Alleghany River. It must originally have spread itself far E. across the Appalachian chain, for it presents its fullest thickness at the more Eastern outcrops left after very extensive denudation. Its attenuated W. or N.W. margin is everywhere under the great Appalachian coal-field. Like the Levant, and some of the earlier formations of the Middle Palæozoic series, this thick but comparatively restricted deposit seems to have been formed in a branch or trough of the sea, nearly coincident with the zone now occupied by the Appalachian Mountains, and part of the great coal-field W. of them, and, as in some of the prior instances, the land-derived materials were probably swept into this slender basin longitudinally, entering it from the N.E., and partially from the E. That these materials were dispersed to so limited a distance W. seems best explained by supposing that newly-uplifted tracts of land, composed of the lately-deposited Vergent series, lay in that direction, for it is hard to understand, if the waters still spread to the W., as in the Vergent period, why these Ponent sediments, quite as impalpable and buoyant as those of the Vergent shales, floated so short a distance ; nor can we comprehend why, if they ceased from expenditure of material, the waters assumed to extend farther West did not precipitate something of a more purely marine character, to remain as a monument of their presence there. We are constrained, therefore, to imagine a very wide and diffused elevation of the crust, changing the level of the sea's bed at the end of the Vergent period, lifting it into dry land W. of the present mountains, but probably depressing it into a comparatively deep slender trough along its S.E. border. The argument for this hypothesis becomes strengthened when we review, as we shall presently, the phenomena of relative distribution of the Vergent and lower carboniferous strata in the Western States.

DEPOSITIONS AND DISTURBANCES OF THE VESPERTINE SERIES.

We come now to the consideration of the conditions under which the first or oldest of the true Carboniferous formations was produced. This Vespertine series betrays, in everything connected with it, a littoral or semi-terrestrial origin. Consisting of grey and yellow sandstones alternating with coarse silicious conglomerates and with dark-blue slates and shales, and containing beds of black carbonaceous slate, and even here and there a thin impure seam of coal ; possessing, moreover, no decidedly marine organic remains, but numerous relics of the terrestrial vegetation, significant of the subsequent coal period,—it is essentially a mass of barren or unproductive Coal-measures, and must be viewed as having been formed under very nearly the physical conditions which attended that important formation. The most material difference in their composition is the absence from the Vespertine series of numerous and widely-extended sheets of coal, a feature which implies, that during its accumulation there were not those repeatedly-recurring intervals of almost absolute repose of the crust, with constancy of sea-level requisite for the growth of the coal-producing meadows, but, on the contrary, that the period was one of more incessant agitation. Possibly, too, the Vespertine strata were formed too much under water, and not, like the Coal-measures, sufficiently near the common limit of air and water to admit sheets of vegetable carbon to be stored up within them. Certainly the physical geography of the period, so far as it is indicated in the respective boundaries of the two formations, was wholly unlike that of the age of the coal. The geographical limits of the Coal-measures, as elsewhere shown, were very broad, the W. verge of the formation lying in Nebraska, Kansas, and Central Texas. Those of the Vespertine strata are much more restricted, being confined to the Appalachian chain on the S.E., and on the N.W. to the Appalachian coal-field, even the N.W. border of which they fail to reach where this basin is broadest in North-western Pennsylvania and Ohio. The area occupied by the whole formation is a long, comparatively narrow zone of country, commencing in N.E. Pennsylvania, and stretching S.W. to North Alabama. Throughout this zone the deposit displays its thickest outcrops along its most Eastern exposures in the mountains, and its actual maximum on the borders of the Schuylkill anthracite coal-field. From this line of its greatest development the mass steadily declines in thickness, and grows less coarse and heterogeneous in composition as it spreads towards the N.W. and W., until it dwindles away entirely before it reaches the place where it should outcrop on the W. edge of the great coal-field in Ohio. Unlike the Ponent stratum underneath it, it does reach the Alleghany River in Western Pennsylvania, though under a very attenuated thickness.

From these facts it would appear that the Vespertine sediments were received in a sheet of waters somewhat coincident in position and limits with that which was previously the receptacle of the underlying materials of the Ponent series, a view corroborative of that already presented, that the close of the Vergent period was an epoch of elevation of a very broad area of the ocean's bed into dry land, in the region now lying to the W. and N.W. of the great Appalachian coal-field.

The materials of the Vespertine rocks, their lessening gradation in size going W., the direction of their bedding, and sundry other phenomena, all concur to suggest that the deposit was chiefly derived by currents and paroxysmal movements of the waters from the E. and N.E., from shores much convulsed by repeated agitations of the crust, but not amounting to undulations productive of permanent flexures.

DEPOSITIONS AND DISTURBANCES OF THE UMBRAL SERIES.

An extensive and marked change arose in the physical geography of the Palæozoic sea at the close of the Vespertine period. Judging from the composition of the Umbral or Middle Carboniferous strata, and the features of their geographical distribution, we must infer that these were deposited under circumstances very dissimilar from those which saw the accumulation of either the Vespertine sediments which preceded them, or the Coal-measures which usurped their place in the ages following. We have mentioned in our description of the Umbral deposits, that in the Appalachian chain the series consists, in its fullest development, which is in Virginia, of buff and red shales below, of a thick limestone in the middle, and of blue, olive, and red marly shales, with red and brown sandstone above; and that in Pennsylvania the whole mass is composed of red shale and argillaceous red sandstone under a maximum thickness, where it surrounds the S. anthracite coal-field of 3000 feet. This great red-shale deposit of Pennsylvania was, it is obvious, collected in a portion of the wide oceanic basin of the period, much more copiously invaded by the washings of adjacent lands than were the districts lying to the S.W. and W. Everything connected with the red shale and sandstone betokens, indeed, an origin contiguous to agitated coasts swept by turbid currents. The total absence of organic remains is an intimation that the sea was too foul with poisonous sediments to permit the presence of the usual marine animals; and the abundance of ripple-marks, sun-cracks, and the specks attributed to rain, and called rain-spots, confirm the impression of the nearness of the land, by giving proof that the layers, while yet freshly deposited, were frequently laid naked to the atmosphere. That they were thus exposed in some localities is, indeed, actually demonstrated by our finding many layers of the rock covered with that polish and those marks of trickling water which never arise in deposits continuously submerged, but are produced solely where an impressible slimy material is left naked by a gentle recession of the precipitating waters. But the crowning proof of all is the occasional occurrence of quadrupedal footprints on these water-marked surfaces, clearly referable to reptilian animals of a batrachian type.

The gradual introduction of a limestone formation in the centre of this shale deposit in the S.W. part of the mountain-chain in Pennsylvania, and its steady enlargement as far at least as the Greenbrier River in Virginia, where its thickness exceeds 1000 feet, is an intimation that a change occurred towards the middle of the period, deepening the bed of the sea for the reception of purely marine matter and of organic inhabitants, and cleansing it of the clayey sediments derived from its E. or N.E. shores.

Crossing the Palæozoic area W. to the W. outcrop of the Appalachian coal-field, we are surprised to find nearly all traces of the red shale, both that underlying and that resting upon the limestone, entirely gone from the series; and upon tracking the deposits from North-eastern Pennsylvania in the same direction W., where no limestone whatever enters the red shale, we perceive that this latter material undergoes a rapid and progressive attenuation, until it vanishes altogether before we reach the waters of the Alleghany River. It would thus appear that the land-derived or argillaceous and sandy beds of the Umbral formation are essentially an E. deposit, and that it was only towards the S.W. that the sea of that epoch precipitated any carbonate of lime; but the area of the Umbral ocean which collected this deposit was a very broad one, for the limestone not only ranges as a continuous stratum from Cambria County, Pennsylvania, to the S. end of the great coal-field in Central Alabama, but it skirts the W. border of that coal-field in Eastern

Kentucky and Middle Tennessee, encloses all but the N. side of the great coal-field of Western Kentucky, Indiana, and Illinois, and even entirely encompasses and underlies the enormous coal-basin which ranges from Central Iowa through Missouri to Western Arkansas. This carboniferous limestone is indeed, to all appearance, the most widely-diffused formation as yet identified by its fossils in North America; for passing under the broad cretaceous basin which fills the plains of Nebraska, Kansas, and Western Texas, E. of the Rocky Mountains, it reappears in that chain, and in the valley of the Rio del Norte, and, plunging under again and again, regains the surface under full development in the Wahsatch Mountains of Utah, and yet farther W. in the Humboldt Chain of the Great Desert. Until its far W. localities are better known, it is impossible to define, even approximately, the limits of this prodigiously broad calcareous sea-bottom; but there is reason to believe that it reaches Vancouver's Island, and that it is the limestone of some of the valleys of the Pacific slope.

The uniform and tranquil physical conditions of the period, implied by the wide diffusion and uniform nature of the deposit, and the character of its organic remains, mark an age which was a fit prelude to the period of the coal-formation which immediately followed, a period in which the geographical scale of action in this quarter of the globe was almost as grand, but which was marked by a uniformity of surface, and of physical and vital conditions wholly different in their nature. I shall present in another place an analysis of the circumstances attendant upon the production of the coal strata.

As the beginning of the Umbral period was marked by a striking change in the state of the precipitating waters, so would seem to have been its close. This latter was evidently attended by a very broad and equal lifting of wide portions of the sea-bed, overspread with its sheet of limestone, and with such commotion in the region of the Appalachian chain, and of the coal-fields W. of it, as far as that of Missouri inclusive, as to strew the uprisen floor with a very broad sheet or sheets of land-derived sandy and pebbly matter, the foundation of the first soil on which the swamps and jungles of the lowest coal-seams of the productive Coal-measures grew. But surpassing this wide-rising of the earth's crust was the sinking of it, which seems to have taken place at the first letting-on of the Umbral waters in which the Carboniferous limestone was to be collected. We have seen that, throughout the Ponent and Vespertine periods, and, we may add, the period of the first half of the Umbral red shale, there could have been no sea W. of the present W. margin of the Appalachian coal-field, as none of these rocks, nor any marine equivalents of them, are discernible at or beyond that boundary. The area of subsidence, therefore, for the reception of the limestone, was almost coextensive with the breadth of the continent. That the ocean came over the dry land, which had remained as such since its upheaval at the close of the Vergent period, gently, and not with paroxysmal violence, is recorded in the universal absence of any widely water-strewn materials between the limestone and the Vergent floor upon which it rests.

As yet we know too little of the strata in and beyond the Rocky Mountains, to speculate respecting the events of the Palæozoic ages on that side of the continent. We must postpone the attempt until further researches accumulate additional data.

The design of the remaining part of the present chapter is to exhibit in a condensed shape some of the most characteristic phenomena of the great coal-formation of the Appalachian region of the United States, to develop the laws which regulate the distribution and order of succession of the strata, and to discuss the theory of their origin.

OF THE LIMITS OF THE APPALACHIAN COAL STRATA.

The extensive Appalachian coal-formation embraces all the detached basins, both anthracitic and semi-bituminous, of the mountain-chain of Pennsylvania, Maryland, and Virginia, and also the vast bituminous trough lying to the N.W. in Pennsylvania, Ohio, Virginia, Kentucky, Tennessee, and Alabama. I shall endeavour presently to show that all these coal-fields, extending from the N.E. counties of Pennsylvania to the N. part of Alabama, and from the great Appalachian valley Westward into the interior of Ohio and Kentucky, include only a portion of the original formation, immense tracts having been destroyed by denudation. A comparison of the coal strata of contiguous basins has convinced me that they are only detached parts of a once-continuous deposit; and the physical structure of the whole region most satisfactorily confirms this idea, by showing that they all repose conformably on the same rocks; the more or less insulated troughs in which they occur, merely being separated by anticlinal tracts of greater or less breadth, from which denuding action has removed the other portions of the formation. This distribution of the coal in a series of parallel and closely-connected synclinal depressions, is a direct result of the system of vast flexures, into which the whole of the Appalachian rocks have been bent, by the undulatory movements that accompanied the final elevation of the strata, and terminated the era of the coal.

Many of the general phenomena about to be described, seem to belong, in an equal degree, to the wide coal-basins of equivalent age, which lie remote from the Appalachian chain, far to the N.W.; namely, that of the State of Michigan, and that which occupies a part of Indiana, Illinois, and Missouri. I shall confine my views for the present, however, to the formation as it is developed in the mountain-basins, and in the great trough or plain which lies immediately to the N.W. of the chain. This last, most Western, or chief Appalachian basin, terminates on the N.E., near Towanda, in Bradford County, Pennsylvania, while its S. point is near Huntsville, in Alabama. The S.E. margin coincides nearly with the main escarpment of the Alleghany Mountain, as far S. as the county of Hardy, in Virginia, beyond which it lies farther to the N.W., following as it ranges through that State, and through Tennessee, the great line of escarpment locally named Laurel Hill, Rich Mountain, Little Gauly Mountain, Great Flat Top, and Cumberland Mountain, ending with the termination of the last in Northern Alabama.

The opposite or N.W. outcrop, commencing likewise at Towanda, extends nearly W. through the N. counties of Pennsylvania to the Alleghany River, at Warren. It here begins to curve gently S., passing through Crawford and Mercer counties, and enters Ohio north of Sharon. Beyond this its general course is about W.S.W. to Akron, where it deflects to the S., so as to pass about 25 miles W. of Zanesville, after which it crosses the Ohio River a few miles above the mouth of the Scioto. Southward from this point the W. line of the coal traverses Kentucky in a S.S.W. direction, passing the Kentucky River near the centre of Estil County, and the Tennessee line a little East of Rock Creek. Ranging through Tennessee, its course is rather irregular, first running S. to Montgomery, thence N.W. to Morgan, and thence by a winding line S. to Sparta, beyond which it stretches S.W. to the termination of the Cumberland Mountain, N.E. of Huntsville.

This enormous tract of the coal-formation is unbroken, except in two quarters: first, near its N.E. termination, and along its N. border in Pennsylvania, where, by the influence of denudation, and a few low anticlinal arches, many small patches of the strata lie insulated from the general mass; and, secondly, along its S.E. side in Pennsylvania, Maryland, and Virginia, where a few bold axes of elevation have thrown the coal-rocks into a series of long, parallel, and nearly united troughs. Considering all of these outlying portions of the formation as subordinate and intimately-connected parts of one great bituminous coal-field, the S.E. boundary of which is the escarpment of the Alleghany and Cumberland mountains, the dimensions of the great basin will be nearly as follows: its length, from N.E. to S.W., is rather more than 720 miles, and its greatest breadth about 180 miles. Upon a moderate estimate, its superficial area amounts to 70,000 square miles.

Though the deep anthracite basins abound in curious structural features, and contain thick seams of coal, they chiefly interest us at present by the geographical position which they occupy. More than 40 miles distant from the general denuded margin of the main or W. coal-field, they nevertheless present, in the character of their strata, and of the rocks upon which they repose, unequivocal evidence that they and the bituminous basins were once united. In this identification we are presented with an amazing picture of the former extent of our carboniferous deposits. The existing S.E. limit of the coal, in these insulated basins, lies, in Pennsylvania, only a short distance to the N.W. of the great Appalachian valley, and a survey of all the circumstances involved in the question of the ancient physical geography of the formation, convinces me that it extended, both in that State and Virginia, at least as far to the S.E. as the great valley. To enter here into all the facts and reasonings upon which this inference is founded, would lead me aside from the main purpose of the present chapter; but I may mention, as one argument, that a group of coal strata, somewhat lower in the formation than the main series, does reach, at intervals, as far E. as the margin of the great valley, in a number of localities between the Potomac River and the Tennessee line. Restricting our attention at present, however, to those districts where the main coal series is developed, we meet with the most ample proofs that all the strata in the insulated basins are precisely on the same geological horizon as those of the great basin W. of the mountains. These coal-rocks all repose conformably on the same easily-recognised formation, the great coal-conglomerate, with the upper beds of which the lower seams are very generally interstratified. This fact, but more especially the circumstance that I have traced many of the principal coal-seams and beds of fossiliferous limestone from basin to basin, fully demonstrates that all these detached troughs, however insulated and remote from the main mass at present, were, at the period of their deposition, united in one continuous formation, which, previously to its elevation and waste by denuding currents, extended from near the E. side of the Appalachian chain to a W. margin at least as distant as the centres of the States of Ohio, Kentucky, and Tennessee.

Here then we have a coal-formation which, before its original limits were reduced, measured, at a reasonable calculation, 900 miles in length, and in some places more than 200 miles in breadth. I would ask, is it conceivable that any lake, bay, or estuary, could have been the receptacle of a deposit so extended, or that any river or rivers could have possessed a delta so vast? The ancient Appalachian ocean grew deeper, as I shall show, towards the W. or N.W.; and inasmuch as rivers push their deltal deposits seawards, and not laterally, and as the carboniferous sediments here to be described are traceable coastwise, as respects this ancient sea, for a length of 900 miles, it is inconceivable how any local fluviatile currents could have assembled them.

NATURE OF THE COAL STRATA.

Assuming it as susceptible of demonstration, that the various coal-basins, bituminous and anthracitic, of Pennsylvania, Ohio, Maryland, Virginia, Kentucky, and Tennessee, were originally united, we may consider the whole as one great formation, in which some highly-interesting gradations in the type and composition of the beds may be traced. To call attention to these phenomena of variation is indeed my main object at this time, since by them only can we arrive at a true theory of the conditions under which the whole were formed. A comprehensive classification of the strata shows the following principal varieties:—

1. Rocks of mechanical origin, of every grade of coarseness, from the smoothest fire-clay to exceedingly rough silicious conglomerates, the whole including within these extremes a wide variety of shales, marls, argillaceous sandstones, and quartzose grits.

2. Limestones, both pure and magnesian, in strata of all thicknesses, from thin bands and narrow layers of detached nodules, to beds measuring from 50 to 100 feet depth. Some of the limestones contain a considerable amount of argillaceous and silicious matter, and many of the thicker deposits consist of alternating layers of limestone and soft shale. Though a few of these calcareous strata are remarkably destitute of fossils, they are rarely found to be altogether deficient in organic remains, when widely and diligently searched; and some of them quite abound in them. It is especially deserving of note, that the genera are such as invariably indicate oceanic habits. This fact is of the more importance, since some of the limestones occur in immediate contact with beds of coal, and with shales and other strata containing the remains of terrestrial vegetation.

Besides the strata of limestone, we meet with other chemically-formed deposits, in the form of numerous seams of carbonate of iron, and a few considerable beds of regularly-stratified chert. The nodular variety of the iron ore is usually imbedded in shale, and lies oftenest adjacent to the coal, while the ore in bands occurs more frequently in contact with the limestone.

3. Coal, in nearly all its known varieties, including every description, from the dryest and most compact anthracites to the most fusible and bituminous kinds of common coal.

Such are the three great classes of strata comprised within the Appalachian coal region of the United States. If we direct our attention to the manner of their distribution, we shall behold some striking and instructive phenomena, susceptible of reduction to regular and harmonious laws of gradation.

Comparing, in the first place, the rocks of mechanical origin as they occur in different districts, we almost invariably find them coarsest and most massive towards the S.E., and more and more fine-grained and less arenaceous as we pursue them across the successive parallel basins N.W. Thus in the anthracite coal-fields, which are the most South-eastern of all, the coal is interstratified with a vast thickness of rough and ponderous grits, and coarse silicious conglomerates, but is associated with comparatively very little soft clay-slate or shale. In this region the coal-slates themselves are more than ordinarily arenaceous, and bear a smaller proportion to the sandstones than in the basins more to the W. At the same time that the coal-rocks, viewed in the aggregate, acquire a finer texture in going W., the individual strata undergo a corresponding reduction in thickness, while many of them entirely thin away. I may cite, as a striking instance of these changes, the great coal-conglomerate itself, which forms the general base of the main or upper Coal-measures. This massive rock is chiefly composed of large quartzose pebbles imbedded in coarse sand. Adjacent to its most S.E. outcrop in Pennsylvania—that is to say, in Sharp Mountain, where it constitutes the boundary of the first or Pottsville basin—it has a thickness of nearly 1500 feet; but in the mountains which embrace the Wyoming coal-field, about 30 miles to the N.W., the thickness of the formation is only about 500 feet; while still farther across the chain, where it becomes the general floor of the Coal-measures under the bituminous form, in the basins N.W. of the Alleghany Mountain, its entire thickness seldom exceeds 80 or 100 feet. Tracing it across the great Western coal-field, until we encounter its last outcrop in Western Pennsylvania, Ohio, and Kentucky, this wonderfully-expanded rock dwindles to a thin bed of sandstone, sprinkled with a few pebbles, its whole thickness amounting generally to only 20 or 30 feet. There is a corresponding and quite as striking a diminution in its constituent fragments, the pebbles in the most S.E. belts of the formation being often as large as a hen's egg, while in the N.W. their diameter is reduced to that of a pea.

A similar gradation obtains in the thickness and coarseness of nearly all the interstratified sandstones and other mechanical members of the formation. I conceive that this interesting fact, fully established by the surveys of Pennsylvania and Virginia, shows beyond all question that the S.E. was the quarter whence the coarser materials of the coal-rocks were derived. But there are not wanting other proofs that the ancient land lay in that direction; these will be presently detailed in describing the gradations witnessed in the limestones and beds of coal. The above general law of distribution relates, it should be observed, only to the coarser mechanical aggregates, since there are some apparent exceptions to its generality among the finer-grained slates and shales. Though the texture of these continues to grow finer as we advance W., some of the strata, when individually traced, seem to increase for a certain distance in thickness. This curious circumstance, which belongs indeed to many of the more argillaceous members of our Appalachian formations, so far from invalidating the above inferences respecting the W. transportation of the sediments, comes beautifully to confirm them, since it is evident, that until a current, holding in suspension a quantity of sedimentary matter, declines in velocity to a certain point, it cannot let fall any considerable amount of the smaller particles. After it has reached a given degree of retardation, the finer materials will subside, and in an increasing quantity, up to a certain point, at which the loss of velocity in the current is compensated by the exhaustion of material, when a gradual and final thinning of the deposit will take place.

If we examine, in the next place, the gradations of thickness visible in the limestones and other marine deposits, they will be found to lead to precisely similar inferences respecting the position of the ancient land. Viewed either together or individually, the limestones of the Coal-measures of Pennsylvania, Virginia, and Ohio, display a remarkably uniform augmentation as we trace them W. Thus, throughout all the S.E. basins, comprising the whole of the anthracite coal-fields of Pennsylvania, and the Broad-Top Mountain in the same State, the formation exhibits a total absence of limestone, and a corresponding deficiency of calcareous matter in the shales and the iron ores. Advancing, however, a distance of 25 or 50 miles N.W. to the general S.E. margin of the great bituminous region, where we enter on the first of the chain of partially-insulated troughs adjacent to the escarpment of the Alleghany Mountain, we no longer encounter a total poverty of limestone, though we still meet with a striking deficiency. As an evidence of this, let us take one of the basins of the Alleghany Mountain—that, for example, which lies near the head of the Potomac River. The minute researches there made in connection with the geological surveys of Virginia and Pennsylvania, have shown that the total thickness of the limestones, counting all the thin bands and layers of nodules, does not probably exceed 10 feet. This statement is confirmed by a pamphlet on the same coal-field, describing the land of the George's Creek Company, by Messrs Alexander and Tyson. In their very full section of the strata, we do not see a single band of limestone introduced.

Turning to the Moshanon basin, in Centre County, which is also a marginal trough of the great W. coal-field, the entire quantity of limestone appears to be about 7 or 8 feet. If, however, we pass W. from this S.E. line, and cross the great coal-fieldby any section between the Susquehanna in Pennsylvania and the Little Kenawha in Virginia, we witness a regularly progressive expansion of the calcareous rocks. In the following tabular statement, which refers chiefly to the Southern counties of Pennsylvania, this gradation is rendered strikingly obvious :—

TABLE FIRST,

Showing the gradual Increase in the aggregate Thickness of the Limestone, as we cross the Southern Coal-field of Pennsylvania, westward.

Broad-Top basin, half-way across the Appalachian chain, ...	*none.*
Potomac basin, near the main escarpment of the Alleghany Mountain, ...	about 10 feet.
Eastern basin of Somerset County, W. of the escarpment, and about 12 miles W. of the Potomac basin,	12 „
Ligonier basin, 20 miles W. of the last, ...	30 „
Second Western basin on the Youghiogheny River, 15 miles W. of the last, ...	about 40 „
Great basin of the Monongahela and Ohio rivers, at Brownsville, probably	60 „
Same basin at Wheeling, ...	about 200 „

The above aggregates admit the more accurately of comparison, since most of them refer to the same portion of the formation—that, namely, which is included between the great conglomerate and the top of the main limestone, above the Pittsburg Coal-seam.

TABLE SECOND,

Showing the Gradation in the Thickness of the large Limestone Stratum overlying the Pittsburg Coal-seam.

Cumberland basin, not more than	2 feet.
Eastern Somerset basin, not determined, but	thin.
Ligonier basin,—average about	7 feet.
Monongahela and Ohio basin, at Brownsville, ...	41 „
Same basin at Wheeling, ...	54 „

In the upper coal group, or that part of the series which commences with the Pittsburg Seam, the total thickness of pure limestone, excluding numerous thin bands associated with some of the layers of shale, is not less than 150 feet.* Some of the limestone strata of the Coal-measures possess, as will be seen from the second of these tables, a remarkably wide distribution, ranging without interruption from the vicinity of the Alleghany Mountain to the country W. of the Alleghany River. Having ascertained the positions of a number of these fossiliferous beds, I am now engaged in investigating their organic remains. The examinations already made show that these all belong to *marine* genera, and that the different beds are characterised by their peculiar species. Many of these beds of limestone have been traced continuously from Northern Pennsylvania to the Kenawha, and from the E. outcrop, near the Alleghany Mountain, to their W. boundary in Ohio. The marine character of their genera—*Terebratula, Goniatites, Bellerophon, Encrinus*, &c.—sufficiently proves that these rocks were originally deposited beneath the waters of an ocean, while, at the same time, the increasing purity of the limestones and the multiplication and expansion of the beds Westward, clearly show that the ancient ocean augmented regularly in depth in that direction. This conclusion, it will be observed, agrees strictly with the results before deduced from the general gradation, visible in the sandstones and other mechanically-formed rocks, which proves that the ancient land was situated towards the E. or S.E. If we examine the relations of the two classes of the coal strata to each other, the land-derived and sea-derived rocks, we perceive that the latter, or the limestones, thicken, going West, at the expense of the former. Frequently two beds approach, and either entirely coalesce, or remain divided by only a thin marly shale, formed from the residual finely-subdivided matter wafted out by the currents, which, farther E., or nearer the land, deposited the coarser and thicker sandstones and arenaceous slates. While this gradation shows itself, new beds of calcareous rock interpolate themselves in new positions in the series, and many of the sandstones thin away and cease altogether, so that the whole formation becomes, by both these changes, more and more oceanic in its type. But the most important result of this mode of tracing the strata is the evidence we have of the frequent alternation of a tranquil and disturbed condition of the waters. Such an intermission of movement and repose will be more fully proved when I come to describe the phenomena connected with the coal-seams. It may be sufficient here to refer to what I have above stated respecting the oceanic and shore rocks, and to appeal to the argument that the coarser or more irregularly strewn the materials of a stratum are, the more violent must have been the current which transported them. With these considerations before us, we cannot fail to perceive in the Appalachian coal strata the monuments of many alternate periods of movement and total or comparative rest. If it be conceded that each of the purer beds of limestone, remarkable for the extreme fineness of their texture and the absence of foreign sedimentary matter, is the index of a longer or a shorter interval of tranquillity in the waters, we shall discern (omitting for the present all similar inferences to be derived from the coal-seams) a much greater number of such separate periods than a mere enumeration of the individual beds would indicate, unless we count the interstratified shales and marls. These last-mentioned strata, generally assuming, as we go E., a thicker and coarser type, furnish as unequivocal a record of disturbances as if the spaces they occupy between the beds of limestone were filled by the coarsest mechanical aggregates.

---

* See "Report of Geological Survey of Virginia for 1840."

One of the most interesting general questions connected with the land and sea produced strata relates to the physical geography of the ancient coast near to which they were deposited, and the inquiry at once suggests itself, whether the receptacle of these various sediments was an extensive estuary receiving the silts of some gigantic river or rivers, or a vast expanse of shallow sea, bounded by a long line of coast, upon which the successive deposits were formed by a very different agency from any we can ascribe to ordinary fluviatile or littoral currents.

OF THE PHENOMENA CONNECTED WITH THE COAL-SEAMS.

Great extent of certain individual coal-beds.—Passing, in the next place, to an examination of the most interesting portion of the coal strata, the coal-seams themselves, we discover in the facts connected with their range and distribution, in the structure of the coal, and in the nature of the beds in immediate contact with the seams, several general laws, tending to afford us a still better insight into the physical conditions which accompanied the production of these strata.

Of the facts connected with the range of the individual coal-seams, that of their prodigious extent is itself one of the most surprising and instructive. As a general rule, this wide expansion characterises all the beds of both the bituminous and anthracitic basins. It is true that many seams possess a comparatively local range, but not a few of those which, on first examination, appear of circumscribed extent, cover in reality a very wide area, the error respecting them being caused by fluctuations of thickness, or by their occasionally thinning out and reappearing. Among those which manifest great permanency as to thickness, the vast range of some of the larger ones is truly extraordinary. Let us trace, for example, the great bed which occurs so finely exposed at Pittsburg, and along nearly the whole length of the Monongahela River, and which I have called the Pittsburg Seam. The high position which this bed occupies in the formation, and the nearly horizontal attitude of all the strata, combine to expose it very extensively to observation, while its great size and the excellence of the coal have caused it to be generally mined. After identifying and tracing it from basin to basin in Pennsylvania, I have been furnished with much information, in relation to its limits and features in Virginia and Ohio, by my brother and Mr Briggs. Guided by the data thus collected, I have been enabled to determine its area and boundaries with very considerable accuracy. The limits of this bed, as at present known, are nearly as follows: That portion, by far the largest part, which is contained in the great Western basin, has its N. termination in Indiana County, in Pennsylvania, and its S.W. on the Ohio River below Guyandotte. The general S.E. outcrop ranges along the W. foot of Chestnut Ridge, or West Laurel Hill, from Indiana County to Tygart's River, in Virginia. It here alters its strike from S.S.W. to a direction more nearly S., passing a little W. of and parallel to Buchanan's River, until it nearly gains the head-waters of the Monongahela. From this point its course is more winding, but the general direction is a little W. of S.W. to the Great Kenawha, which it crosses between Charlestown and the Pocatalico Creek. From the Kenawha it ranges nearly W. to the Ohio River, between Guyandotte and Burlington, where, crossing that great stream into the State of Ohio, it sweeps rapidly North. Its outcrop, now following the W. margin of the basin, preserves a general N.N.E. direction as far as McConnellsville, on the Muskingum. Beyond this point it stretches in a N.E. course until it recrosses the Ohio River a little above Steubenville, where it soon reaches the W. line of Pennsylvania, in Beaver County. Here the edge of the seam turns E., and crosses the Ohio River once more, a few miles below Pittsburg and the Allegheny River, some miles N.E. of that town. E. of this point it pursues a more devious line, the meanderings of which are caused by three parallel anticlinal axes, crossing the Kiskiminetas and Conemaugh rivers. Being thrown into a very irregular and curving outcrop by these elevations, it finally joins the S.E. margin at the N.E. extremity of the basin in Indiana County, the point from which we set out. The longest diameter of the great elliptical area here delineated is very nearly 225 miles, and its maximum breadth about 100 miles. The superficial extent of the whole coal-seam, as nearly as I can estimate it, is about 14,000 square miles.

But the limits here described, though wide, fall very far within those which the bed anciently occupied. To the S.E. of the large basin of the Ohio River there are several other insulated parallel troughs, which also contain the Pittsburg Seam. Of these, the farthest from the main coal-field is that at the head of the Potomac River, at a distance of about 43 miles in a straight line. The E. margin of the Pittsburg Bed is here, however, nearly 50 miles E.S.E. of the E. edge of the same seam in the main or W. basin, and it has a corresponding expansion E. in other districts. That this coal-bed preserves an unbroken range for many miles to the N.E. of the termination of the principal basin in Indiana County, appears highly probable, from a comparison of the Coal-measures at certain localities in that quarter. I shall not, however, assume the known length of the tract actually occupied by it as exceeding the above-mentioned 225 miles, throughout which it is uninterruptedly traceable. If we now take into account the 50 additional miles of breadth which the bed once possessed, its former area must have been at least 34,000 square miles, a superficial extent greater than that of Scotland or Ireland.

Though the above is perhaps the greatest extent of surface which it is in our power positively to assign to this bed of coal, the proofs of a prodigious denudation of the strata, throughout the districts bordering its present outcrop, are so irresistible that I consider the dimensions here given as bearing actually but a small proportion to the real ancient limits of the stratum. But restricting our attention for the present to those limits which it did undoubtedly once occupy, it is still by far the most extensive coal-bed yet explored in any country; and the mere fact of its great extent must exert an influence on our views concerning the conditions under which the whole coal-formation originated.

The general uniformity in the thickness of this superb bed, throughout so vast a region, and at the same time the regular and gentle gradation which it experiences in size when we trace it from one outcrop to the other, are features not less remarkable than its enormous length and breadth. In the most South-eastern basins, where it is most developed, its total thickness is from 12 to 14 feet; while in the basins between Chestnut Ridge and the Monongahela River, it usually measures from 10 to 12 feet. Still farther to the W., between the Monongahela River at Brownsville, and the Ohio at Wheeling, it declines from about 10 to 8 feet, and beyond this, in the State of Ohio, it seldom exceeds 5 or 6 feet. Following it longitudinally, or in the direction of the great elliptical basin, it displays quite as remarkable a persistency in its dimensions, the reduction in its size being, if anything, still more gradual from N.E. to S.W. Thus, at Pittsburg, it measures altogether about 8 feet; at the mouth of Big Grave Creek, rather more than 5; on the Great Kenawha, about 5; and from this point to Guyandotte, where it terminates, 3 feet; and, finally, hardly 2 feet. Tracing it along a parallel line from N.E. to S.W., but nearer its S.E. outcrop, we detect the same very gradual abatement in its thickness. While we are thus furnished with conclusive evidence, from the fact that its rate of increase is most rapid towards the S.E., that the ancient land with which the stratum was connected must have been situated in that direction, we see that the N.E. part of the coast was the quarter where its materials were supplied in the greatest abundance. To this conclusion I am disposed to appeal, in support of the conjecture already ventured, that this great bed of the main or W. coal-field is but a remnant of a still more expanded stratum, which attained its maximum size in the enormous seam of which all the anthracite basins present us insulated patches. The singular constancy in the thickness of this Pittsburg Bed, no less than its prodigious range, are circumstances that seem strongly adverse to the theory which ascribes the formation of such deposits to any species of *drifting* action. But a more thorough discussion of this question will be attempted presently.

OF THE INTIMATE MECHANICAL STRUCTURE OF THE COAL.

An examination of the structure of the coal itself, apart from the fact of the great range and uniformity in the thickness of the beds, renders it apparent that no irregular dispersion of the vegetable matter by any conceivable mode of drifting, either into estuaries or the open sea, could produce the phenomena which they exhibit. The mechanical arrangement of the layers in every coal-seam, as seen when viewed edgewise, indicates plainly that it is a compound stratum as much as any other sedimentary deposit, each bed being made up of innumerable very thin laminæ of glossy coal, alternating with equally minute plates of impure coal, containing a small admixture of finely-divided earthy matter. These subdivisions, differing in their lustre and fracture, are frequently of excessive thinness, the less brilliant leaves sometimes not exceeding the thickness of a sheet of paper. In many of the purer coal-beds, both anthracitic and bituminous, these thin partings between the more lustrous layers consist of little laminæ of pure fibrous charcoal, in which we may discover the peculiar texture of the leaves, fronds, and even the bark of the plants which supplied a part of the vegetable matter of the bed. If traced out to their edges, all these ultimate divisions of a mass of coal will be found to extend over a surprisingly large surface when we consider their minute thickness. Pursuing any given brilliant layer, whose thickness may not exceed the fourth part of an inch, we may observe it to extend over a superficial space which is wholly incompatible with the idea that it can have been derived from the flattened trunk or limb of any arborescent plant, however compressible. When a very large block of coal is thus minutely and carefully dissected, it very seldom, if ever, gives the slightest evidence of having been produced from the more solid parts of trees, though it may abound in fragments of their fronds and deciduous extremities. The laminæ of brilliant carbonaceous matter almost invariably thin away to a fine edge before they terminate, a fact which of itself seems to prove that the material was in a soft or pulpy state at the time of its accumulation, and this supposition receives countenance from the homogeneous texture and conchoidal fracture of every such layer.

Granting the correctness of this inference, which is not in conflict with the beautiful microscopic determinations by Hutton respecting the traces of vegetable structure in certain portions of coal, the argument seems almost conclusive that the vegetable matter grew where it was deposited. It is difficult to understand why the coal should not consist principally of the larger parts of trees—such as their trunks, limbs, and roots—if any species of drifting operation brought together the materials of the bed, by conveying seawards the growth of ancient forests. The leaves and other fragile parts would soon become detached on the voyage, and these, together with the smaller plants, would subside and get imbedded long before the trunks and lighter woody parts could grow sufficiently waterlogged to sink. It is obvious that a stratum formed by the successive deposition of huge irregular stems and branches, would exhibit, no matter what might be the subsequent pressure, a very different structure from that thin and uniform lamination which distinguishes all beds of coal. These considerations, derived from the mechanical features of every seam of coal, receive strong confirmation from the microscopic researches of Mr Hutton. Though that observer found more or less of the cellular vegetable structure in each of the three varieties of Newcastle coal, he discovered a complete obliteration of the characteristic cells in those finest lustrous portions of the caking coal, where the crystalline structure, as he terms it, is best developed. Besides the above-mentioned features, all the coal-beds which I have ever examined, or seen minutely described, possess another peculiarity in their mechanical constitution, on a less minute scale, which is equally incompatible with the notion of transportation by currents. I refer here to the subordinate divisions of the coal-beds, some of which are strata of pure coal, some of earthy coal, and some of common shale, all constituting together the compound mass which we call a coal-seam, but each maintaining its particular position and character as a distinct deposit over an area which is truly astonishing. Those persons who are conversant with large mining districts are aware of the many instances of remarkable persistency in these subdivisions in the coal-beds, since it is frequently by their means that the miners recognise a known coal-seam in cases of difficulty. Thus the largest bed of the anthracite fields of Pennsylvania contains almost everywhere a particular band of unusually pure coal, not far from the bottom, generally from 3 to 4 feet in thickness. A still more striking example occurs in the great Pittsburg Bed already spoken of. If we dissect this compound mass, and trace the several divisions, we become impressed with the wonderful distances to which some of them extend. Not to enter here into a minute discussion of all the features of this widely-distributed seam, it will suffice to state that it consists principally of three members which are readily recognised. The lowest is a thick bed of uncommonly pure coal, the middle a layer of soft shale or fire-clay, about 1 foot in thickness, and the uppermost, or roof coal, is itself a compound seam, 2 or 3 feet thick, of alternating layers of coal and fire-clay. Now it is a highly-instructive fact, that this general triple subdivision prevails throughout nearly the whole range of the seam from its E. to its W. outcrops, and from the Conemaugh in Pennsylvania into Western Virginia, for a distance of more than 200 miles, from N.E. to S.W. But besides this fact, each subordinate portion preserves its own distinctive features, the upper member being everywhere remarkable for its alternation of thin bands of coal and shale. Can any evidence be more conclusive as to the uniformity of the conditions under which every part of this coal-bed was produced? There must, indeed, have prevailed an almost perfect uniformity in the state of the surface throughout the vast area which it occupies, as respects even the formation of the thinnest of these subdivisions. Such remarkable sameness of action throughout the same geological horizon, appears absolutely incompatible with any mode of drifting of the vegetable matter. Only one particular process of accumulation appears to explain the occurrence, in such cases, of these thin and uniform sheets of material, of which the thickness is often less than a foot, while their superficial area is many hundred square miles. I cannot conceive any state of the surface adopted to account for these appearances, but that in which the margin of the sea was occupied by vast marine savannahs of some peat-creating plant, growing half-immersed on a perfectly horizontal plain, and this fringed and interspersed with forests of trees, shedding their leaves upon the marsh. Such are the only circumstances under which it is likely that these regularly parallel, thin, and widely-extended sheets of carbonaceous matter, could have been accumulated.

Independently of the above argument, based on the breadth and uniform distribution of the layers in the coal there is another, drawn from the striking deficiency of earthy sedimentary particles. In many of the purest layers, the total proportion by weight of foreign mineral substance in the coal, is less than two per cent, sometimes barely one per cent, while the ratio by bulk is consequently less than one half of this. So extremely insignificant a quantity is what we should expect, on the hypothesis of a tranquil accumulation in wide sea-meadows, extending far out from the edge of the ancient shore, where no turbid currents could get access. It is as inconsistent, on the other hand, with the notion of a drifting of the vegetable matter itself, which, according to any conceivable mode of transportation, would be accompanied by a large amount of earthy matter, such as abounds in all deltal deposits, and even mingles with the wood in the raft of the Atchafalaya. That so nearly the whole of the suspended mineral matter, even to the fine particles of impalpable clay, should have subsided, in almost every instance, before the first portions of the floating vegetation sank, contradicts all observation respecting similar actions now occurring. The introduction of any argillaceous matter into the transparent waters of the great peat-morasses, must have happened in the manner of an exceedingly quiet and diffused silting in, or more properly a slow intermingling, of very slightly turbid water with that of the limpid sea. The above arguments from the uniformity in the distribution of the vegetable matter of the coal-seams, and from the absence of earthy matters in the coal, have been already employed by Mr Beaumont as objections to the drift theory, in a communication read to the Geological Society of London, February 26th, 1840.*

OF THE CHARACTER OF THE STRATA IN IMMEDIATE CONTACT WITH THE COAL-SEAMS.

Turning from the structure of the coal itself to the character of the strata usually in immediate contact with it, we discover certain prevailing relations, from which, by a careful study, much light is to be derived, both as to the statical conditions and the order of the physical events which attended the production of the whole coal-formation. There is an interesting and characteristic difference, in point of composition and structure, between the beds bounding the upper and lower surfaces of every coal-seam. This, though of great significance in its bearings on the theory of the formation of coal, has never been distinctly examined with that view.

Of the Material underlying the Coal-beds.—The deposit upon which each seam of coal immediately rests, and which I shall call the floor, is, with a few rare exceptions, wholly distinct in its composition from the roof, or that which reposes directly upon the bed. To Sir William Logan we are indebted for having ascertained the highly important fact, that the floor of every coal-seam in South Wales is composed of a peculiar variety of more or less sandy clay, distinguished by its containing the *Stigmaria ficoides*. "Portions of the stem of the *Stigmaria* are found in other parts of the Coal-measures, but it is only in the under clay that the fibrous processes are attached to the stem, or associated with it."† Since the publication of his *Observations on the Stigmaria Beds of South Wales*, the same gentleman has extended his researches to the United States, and has found our own coal-seams in Pennsylvania to be similarly accompanied.‡ Sir Charles Lyell has also shown that this peculiar stratum underlies the bituminous coal-beds at Blossburg, in Pennsylvania. I visited, with that eminent geologist, the anthracite beds of the Pottsville and the Beaver Meadow basins in Pennsylvania, where we found the Stigmaria bed, in the same position, below those seams. Still more recently, I have ascertained, from my own notes on the geological survey of Pennsylvania, and from those of my brother in relation to Virginia, that this deposit accompanies nearly every coal-bed in the great bituminous coal-region W. of the Alleghany Mountain. I shall take occasion presently, however, to point out some peculiar exceptions to its general prevalence. The theoretical importance of this generalisation concerning the Stigmaria, and the fire-clay enclosing it, appears to have been discerned by Sir William Logan, but he has not offered any explanation of the fact;—the following passage from the published abstract of his paper conveys his views: "When it is considered that, over so considerable an area as the coal-field of South Wales, not a seam has been discovered without an under-clay abounding in Stigmaria, it is impossible to avoid the inference, that there is some essential and necessary connection between the existence of the Stigmaria and the production of the coal. To account for their unfailing combination by drift seems unsatisfactory; but whatever may be the mutual dependence of the phenomena, it affords reasonable grounds to suppose that the *Stigmaria ficoides* is the plant to which we may mainly ascribe the vast stores of fossil fuel." I am not aware that either Logan or any other geological writer has attempted to account for the great frequency of this stratum immediately underneath the coal, or that any hypothesis has been advanced to explain the general prevalence in it of the Stigmaria, and the absence of all those other species of plants which abound among the layers of the coal itself, and in the roof and other overlying rocks. One main object of the following theory of the origin of the Coal-measures is to attempt the solution of these curious facts. §

---

* Beaumont, "Proceedings of the Geological Society," No. 69. † Logan, *Ibid.* ‡ *Ibid.*, for April 1842.

§ Since this memoir was written, my attention has been called by my brother, Prof. Wm. B. Rogers of Virginia, to the splendid work of Mr Edward Mammatt, on the Coal-Field of Ashby de la Zouch, published in 1834. This elaborate description contains a clear announcement of an under clay for almost every coal-seam, and mentions, moreover, the presence "of a distinct single vegetation" in that of the *main coal*, with other facts and suggestions, since confirmed by Mr Logan (now Sir William Logan), and several other recent writers on the origin of the coal strata. I cannot find that the obvious claims of Mr Mammatt to priority as a discoverer in this interesting subject have been anywhere acknowledged. It is to be regretted that the still earlier opinions of Werner, De Luc, and Adolph Brongniart, attributing the vegetable matter of the coal-beds to a growth on the spot where the coal now exists, should have escaped so generally the attention of British geologists, with the exception of Mr Lyell (now Sir Charles Lyell).‖

The following passages from Mr Mammatt's work will convince us how very near he was to a clear conception of the relations of the Stigmaria, and to a sound doctrine of the circumstances under which the coal-beds were accumulated: "Seams of fire-clay abound in the Ashby coal-field, and there are very few coal-measures (coal-seams?) which do not rest upon it, as the Sections will show." And again: "From the circumstance that so many cases occur where a tolerably pure fire-clay lies immediately under and in contact with a

---

‖ After this paper was written, Dr Buckland's admirable "Anniversary Address to the Geological Society of London, for 1841," appeared, in which he mentions that this doctrine has been entertained by De Luc, MacCulloch, Jameson, Brongniart, Lindley, and other writers.

The Stigmaria presented in its structure, according to Lindley and Hutton, a low, dome-shaped, fleshy trunk, or centre, from the edge of which there radiated a number of horizontal branches, supplied with a multitude of slender, cylindrical, and exceedingly long leaves. The fire-clay, or Stigmaria clay, as we may indifferently call it, abounds in these delicate leaves, in a flattened and distorted condition; and it is partly to them, and partly to the comminuted state of the argillaceous material itself, that the stratum owes its characteristic tendency to crumble in every direction. The branches of the Stigmaria, which usually lie parallel to the plane of the stratum, and are most abundant nearest the coal, it has been suggested, were hollow cylinders, composed entirely of spiral vessels, and contained a thick pith. The plants, according to Dr Buckland, probably floated on the water.

Such were the views entertained of the nature of Stigmaria at the time this essay was written (1842); but subsequent researches by M. Brongniart rendered it probable, and actual observation by Mr Binney of Manchester, made a little later, proved, that Stigmaria is simply the *root* of *Sigillaria.*

OF THE ROOF OF THE COAL.

If we examine, in the next place, the strata which immediately rest upon the coal, we shall discover a condition of things in striking contrast with the phenomena of the under-clay. Instead of one uniform material almost invariably present, composed of finely-divided particles, the beds overlying the coal consist of nearly every variety of rock embraced in the formation, though they are more usually some form of laminated carbonaceous slate. Both in its composition and structure, the roof rock manifests signs of having been deposited by a more or less rapid current. In place of a single species of fossil plant, it usually includes a prodigious variety; and the delicate ramifications of these, instead of intersecting the bed in various directions, as the processes of the Stigmaria do in the fire-clay, lie in a singularly disordered and fragmentary condition, in planes almost invariably parallel to the bedding. Lindley and Hutton, in their work on the *Fossil Flora of Great Britain,* give the following very accurate description of the mode in which the organic remains occur in the roof-slates in England, and the account is equally applicable to those of the United States: "It is the beds of shale, or argillaceous schistus, which afford the most abundant supply of these curious relics of a former world, the fine particles of which they are composed having sealed up and retained in wonderful perfection and beauty the most delicate forms of the vegetable organic structure. Where shale forms the roof of the workable seams of coal, as it generally does, we have the most abundant display of fossils. The principal deposit is not in immediate contact with the coal, but from 12 to 20 inches above it; and such is the immense profusion in this situation, that they are not unfrequently the cause of very serious accidents, by breaking the adhesion of the shale-bed, and causing it to separate and fall, when, by the operation of the miner, the coal which supported it is removed. After an extensive fall of this kind has taken place, it is a curious sight to see the mine covered with these vegetable forms, some of them of great beauty and delicacy; *and the observer cannot fail to be struck with the extraordinary confusion, and the numerous marks of strong mechanical action, exhibited by their broken and disjointed remains.*" Such is the nature of the roof when it consists of the usual carbonaceous shale or slate; but in the Appalachian coal-fields it is oftentimes a much coarser rock, being either an argillaceous flaggy sandstone, or a coarse arenaceous grit, or even occasionally a silicious conglomerate. In these instances the enclosed vegetable remains are for the most part fragments of the larger stems or branches of gigantic arborescent plants, their fronds and leaves being less abundant. These fragments occur in all postures as respects the plane of the bedding—horizontally, obliquely, or perpendicularly; and betray, in their broken condition and irregular mode of dispersion, the sudden and tempestuous character of the currents which drifted and entombed them. Though the arenaceous rocks having these features sometimes rest in immediate contact with the upper surfaces of the beds of coal, they more frequently lie at a moderate distance over them, an argillaceous laminated slate interposing to form the actual roof. A further indication of the violence of the currents which strewed these coarse materials over the coal is sometimes to be detected in the composition of the lowest portion of the overlying bed of grit or sandstone, in which a large amount of coal, in the state of powder or sand, is disseminated in the rock, giving it a dark speckled appearance. This is of very common occurrence in the anthracite

bed of coal, it may be inferred that such clay stratum could not have been the soil where the vegetable matter grew which produced the coal, unless this vegetable matter was a moss, a peat, or some aquatic plant; because in the clay there is no appearance of trunks or other vegetable impressions, beyond slender leaves, as of a long grass.

"The fact that particular strata accompany the main coal for many square miles would support the idea that an immense flat was originally covered with the substance of this fire-clay many feet thick, and that upon this flat there took place a uniform growth of a distinct single vegetation, which must have occupied the position for a long period, and thus furnished the substance which composes the *main coal.* The alternations of fire-clay and coal-seams would favour the notion that these materials were originally mixed together in a fluid, and that those of the former, by their gravity, would first subside, whilst the vegetable matter, or those of the latter, would undergo a more gradual deposition. Hence, by a repetition of the process, the alternations of the strata would be produced. Besides, it may be supposed that if the strata of coal have derived their origin from the growth and destruction of a forest, some portions of them would have been thicker than others, and altered in quality, or have retained at least some traces of forest trees; whereas, on the contrary, most extraordinary uniformity in quality, compactness, and thickness of the seams, prevails to a great extent." *

---

* *Geological Facts,* by EDWARD MAMMATT, p. 73.

coal-strata of Pennsylvania, where the coarse grit not unfrequently rests immediately on the coal. It implies, I conceive, the erosion of a certain portion of the upper surface of the soft carbonaceous mass by the friction of the sandy current. The coaly matter, thus disturbed, would subside with the first layers of the sand with which it was mingled. Sir William Logan has mentioned a still more striking proof of the energy of the movements which occasionally occurred during the formation of the Coal-measures. He gives an account of actual boulders, or rounded pebbles of coal, in the Pennant grit, and other coarse strata of the coal-field of South Wales.

OF THE DIRECT CONTACT OF COAL-BEDS AND MARINE LIMESTONES.

In the preceding account of the strata immediately below and above the seams of coal, I intentionally omitted to introduce the limestones which occasionally compose the floor or the roof, sometimes in direct contact with the coal. The portion of the Appalachian coal-formation in which this remarkable contiguity of marine calcareous strata and vegetable or terrestrial coal occurs, is the great W. basin of the Alleghany and Ohio rivers. I have already mentioned the abundance of unquestionably oceanic limestones in this coal-field, and stated my inferences from the interesting fact, that they augment in thickness and multiply in number in crossing the region N.W. As, however, the actual contact of beds of coal and limestone is of rare occurrence in the coal-fields of other countries, and as the circumstance must have an influential bearing on all our speculations concerning the physical conditions prevailing at the formation of the strata, and, to a certain extent, on our whole theory of the origin of coal, I shall here describe some of the best-known instances before I reason concerning them.

Confining our attention to the great W. basin, where the most striking cases occur, the following instances of this contact present themselves in the ascending order :—

First. In the lower division of the main Coal-measures there occurs, near the town of Mercer in Pennsylvania, a seam of good coal, having a thickness of about 2 feet, which is immediately overlaid by a bed of very pure limestone, also about 2 feet thick, containing a variety of marine organic remains of the genera *Terebratula*, *Bellerophon*, &c. In some spots the pure coal is not separated from the pure limestone by more than a single inch, or at most 2 inches, and then the interval is filled with a calcareo-carbonaceous shale.

Secondly. Higher in the series, but still in the lower part of the main Coal-measures of Western Pennsylvania, we meet with a bed of fossiliferous limestone, the thickness of which, in many neighbourhoods near the Alleghany River, is about 15 feet. It contains several oceanic species, among them some *Crinoideæ*, two species of *Terebratula*, and a *Goniatites*. In some places this stratum embraces a thin seam of coal, 4 inches thick, in almost direct contact with the limestone.

Thirdly. The limestone, which is the first underneath the Pittsburg Seam, contains a bed of coal 1 foot in thickness, separating two of its lower layers.

Fourthly. Near Pittsburg, the great coal-seam frequently rests within a few inches of this underlying limestone, in which are a few occasional fossils, all of marine genera. In these places the dividing layer is only a few inches thick, and consists of a bluish fire-clay.

Fifthly. In Fayette County, Pennsylvania, the great limestone, which lies above the Pittsburg coal-bed, encloses very generally two thin seams of perfect coal, immediately in contact with the layers of the rock. These coals appear to have a considerable range, extending into the adjoining counties. The largest is occasionally 2½ feet thick, and a few inches of black calcareous slate alone separate it from the hard limestone. The other coal-bed has a thickness of about 1 foot, and its surfaces are in equally close contact with the limestone. Neither of these beds is as widely expanded as the including limestone.

Sixthly. Underneath the uppermost workable bed of coal in Western Pennsylvania, or that which I have termed in my Reports the Waynesburg Seam, there is a stratum of limestone, which sometimes encloses a thin coal-bed, measuring about 1 foot.

Seventhly. At Putnam Hill, near Zanesville, in Ohio, a bed of limestone, 5 feet thick, rests, according to Dr Hildreth, on a seam of coal 1 foot thick, there not being more than 2 inches of fire-clay interposed. The limestone contains *Encrini*, *Terebratulæ*, and other marine fossils.*

Eighthly. The same writer mentions that, on the Clear Fork of Little Muskingum, in Ohio, there is a seam of good bituminous coal, 3 feet thick, reposing directly on a dark, carbonaceous, fossiliferous limestone 8 feet in thickness. It is overlaid by another limestone, measuring 6 feet, from which it is separated by a very thin layer of shale.

Ninthly. Dr Hildreth further states, that on Wills's Creek, in the same region, a coal-seam 5 feet thick occurs, resting immediately on a bed of limestone, the thickness of which is 20 feet.

I might cite a large additional number of cases in Pennsylvania, Virginia, and Ohio, in proof of the frequency of the contact of the coal-seams and beds of limestone; but I have been disposed to establish the fact chiefly from instances in different portions of the formation, and to show that the contiguity of the coal and limestone is often maintained throughout a considerable extent of country.

---

* HILDRETH, in *American Journal of Science*, p. 31.

THEORY OF THE ORIGIN OF THE COAL STRATA.

Having presented what, I trust, is a sufficiently full sketch of the leading phenomena of the Appalachian Coal-measures, and shown their correspondence, in several essential features of structure, to the coal-formation of Europe, I shall proceed now to consider what inferences we are entitled to draw respecting their origin, and that of the coal-formation generally. But before taking this theoretical survey, it will be expedient to state succinctly the views of the several eminent geologists who have recently written on this subject. I feel it the more incumbent to do this, since some of the speculations I shall advance are but modifications of hypotheses already published.

From a passage in Lyell's admirable work, *The Elements of Geology,* it appears that M. Adolphe Brongniart, after comparing the phenomena of the ancient coal and its fossil plants with the great peat-mosses of the present day, states, in a memoir published in 1838, that he continues to adhere to the opinions originally advanced by Werner and De Luc, that the vegetation entombed in the carboniferous strata chiefly grew in the localities where the coal is now found.* Whether M. Brongniart, however, endeavours to conform this view to all the phenomena of the Coal-measures under any general theory of their origin, I am not informed, not having seen his memoir.

Mr Hawkshaw, in a communication to the Geological Society of London in 1839, describes the remarkable phenomenon of five fossil trees, exposed in a cutting on the Manchester and Bolton railway, standing erect in relation to a bed of coal, 8 or 10 inches thick, and in the same place with their roots. The largest of these was 5 feet in diameter at the base, and 11 feet high. He conceives it probable that they grew where they occur.† In a subsequent paper, read February 26, 1840, Mr Hawkshaw, after mentioning the discovery of another fossil tree, standing on the same coal-seam, makes this observation: "If the coal be considered as the debris of a forest, it is difficult to account for not finding more trunks of trees than have been discovered in our coal-basins; and it is only, perhaps, by allowing the original of our coal-seams to have been a combination of vegetable matter, analogous to peat, that the difficulty can be solved." ‡

After Mr Hawkshaw's first communication, Mr Beaumont, in a paper read to the same Society, November 6, 1838, upon the subject of the same trees, states several objections to the drift theory of coal, and conceives that the vegetation grew where it is found. Upon comparing these objections with my own, as given in the foregoing pages, I find that they all rest upon a different class of facts, and are wholly distinct in their bearings. Mr Beaumont states that the vegetation which formed the coal grew on swampy islands, that it consisted of *ferns, calamites, coniferous trees,* &c., which operated, through their decay and regeneration, to form peat-bogs; and that the islands, by subsiding, were covered with drifted sand, clay, and shells, till they again became dry land, and supported another vegetation; and this process, he supposes, was repeated as often as there are coal-seams.§

Dr Buckland, in commenting on this hypothesis, observes, that, "in denying altogether the presence of drifted plants, the opinion of the author seems erroneous; universal negative propositions are in all cases dangerous, and more especially so in geology. That some of the trees which are found erect in the coal-formation have not been drifted, is, I think, established on sufficient evidence; but there is equal evidence to show that other trees and leaves innumerable, which pervade the strata that alternate with the coal, have been removed by water to considerable distances from the spots on which they grew. Proofs are daily increasing in favour of both opinions, namely, that some of the vegetables which form our beds of coal grew on the identical banks of sand and silt and mud, which, being now indurated to stone and shale, form the strata that accompany the coal; whilst other portions of these plants have been drifted to various distances from the swamps, savannahs, and forests, that gave them birth; particularly those that are dispersed through the sandstones, or mixed with fishes in the shale beds. || In these views of Dr Buckland Sir Charles Lyell would seem to concur, as, in quoting the above passage in his Elements, he says that "it can be no longer doubted that both these opinions are true, if we confine our attention to particular places."

Another paper, on the same subject of the fossil trees, found on the Manchester and Bolton Railway, was read contemporaneously with the last communication of Mr Hawkshaw. The author, Mr Bowman, is of opinion "that the theory of the subsidence of the land during the carboniferous era, receives much support from the phenomena presented by these fossil trees." He does not deny that plants may have been carried into the water from neighbouring lands; but he conceives it difficult to understand whence the vast masses of vegetables necessary to form thick seams of coal could have been derived, if drifted, and how they could have been sunk to the bottom without being intermixed with the earthy sediment which was slowly deposited upon them. Another difficulty of the drift theory, he says, "is the uniformity of the distribution of the vegetable matter throughout such great areas as those occupied by the seams of coal." I have myself shown that this uniformity extends even to the subordinate divisions of each seam. Mr Bowman believes that the coal has been formed from plants which grew on the areas now occupied by the seams; that each successive race of vegetation was gradually submerged beneath the level of the water, and covered up by sediment, which accumulated till it formed another dry surface for the growth of another series

---

* Lyell's *Elements*, ii. 135, Boston edition.

† Hawkshaw, in "Proceedings of the Geological Society, London," No. 64.

‡ *Ibid.*, No. 69.

§ Beaumont, in "Proceedings of the Geological Society, London," No. 65.

|| Anniversary Address to the Geological Society, 1841.

of *trees* and plants, and that the submergences and accumulations took place as many times as there are seams of coal.

In reviewing the above facts and opinions, Dr Buckland conceives that a luxuriant growth of marsh plants, as *Calamites*, *Lepidodendra*, *Sigillaria*, &c., may have formed a superstratum of coal, resting on a substratum of the same, composed exclusively of remains of *Stigmariæ ;* and in accounting for the marine and fresh-water strata alternating with the coal-beds, he appeals to the intermitting and alternate processes of subsidence, drift, and vegetable growth.[†]

The above summary of the recent researches and speculations of geologists, conveys, I believe, a correct view of the state of opinion at the present time, in relation to the interesting problem of the origin of the coal strata. I may now venture to advance my own explanation of the phenomena, and to indicate wherein I differ from the able authors I have cited. The several hypotheses proposed, do not attempt to account for some of the most remarkable relationships among the strata, such as the extraordinary frequency, beneath the coal-beds, of the Stigmaria clay, the very general occurrence of laminated slates immediately above the seams, and the singular contrast which these underlying and overlying rocks present, in the variety and condition of the imbedded vegetable remains. Nor do they explain satisfactorily why the coal itself contains so few traces of the forest trees of the period, either in a prostrate or erect position ; while their broken stems are mingled with the fragmentary parts of the Stigmaria, in more or less abundance, in all the coarser rocks. Perhaps the following hypothesis will account for the phenomena.

Let us imagine the areas now covered with the coal-formation, to have possessed a physical geography, in which the principal feature was the existence of extensive flats, bordering a continent, and forming the shores of an ocean, or some vast bay, outside of which was a wide expanse of shallow but open sea. Let us now suppose that the whole period of the Coal-measures was characterised by a *general* slow subsidence of these coasts, on which we conceive that the vegetation of the coal grew ;—that this vertical depression was, however, interrupted by pauses and gradual upward movements of less frequency and duration, and that these nearly statical conditions of the land alternated with great paroxysmal displacements of the level, caused by those mighty pulsations of the crust which we call earthquakes. Let us further conceive, that during the periods of gentle depression, or almost absolute rest, the low coast was fringed by great marshy tracts or peat-bogs, derived from and supporting a luxuriant growth of *Stigmariæ* (*Sigillaria* and *Lepidodendra*), and that along the landward margin, and in the drier places of these extensive sea morasses, grew the *Coniferæ*, *Tree-Ferns*, *Lycopodiaceæ*, and other arborescent plants, whose remains are so profusely scattered throughout the coarser strata between the coal-seams. In this condition of things, the constant decomposition and growth of the meadows of *Stigmariæ* would produce a very uniform, extended stratum of pulpy but minutely-laminated pure peat. This would receive occasional contributions from the droppings by the scattered trees of their leaves, fronds, and smaller portions, which, being driven by winds or floated on the high tides, would lodge among the Stigmariæ in the marshes, and slightly augment the deposit. These leaves and fronds, covered over more or less rapidly by the growing *Stigmariæ*, or varying in their tendency to decay, according to the abundance or deficiency of their juices, would, when thus enclosed, pass at once either to the pulpy state, and ultimately form coal, or, by the more rapid extrication of their volatile portions, remain as mineral charcoal, and preserve their vegetable fibrous structure. In both of these conditions of coal and charcoal, we often find the smaller parts of plants retaining their organised forms among the laminæ of the purest coal-seams. Upon this view of a gradual accumulation from the *Stigmariæ*, assisted by the deciduous parts of the trees, it is altogether unnecessary to suppose that any portions, even the upper layers of the coal-beds, derived their vegetable matter from the stems of the trees themselves. Thus the absence of trunks and roots from the coal is reconciled with the occasional occurrence of their fronds and lighter extremities. Upon no other hypothesis respecting the physical condition of the region which produced the coal vegetation than that here imagined, can I explain the singular infrequency of fossil trunks standing on or in the coal, or account for their occasional occurrence, as in the instances described by Hawkshaw and Bowman. No other supposition seems to furnish a cause for the absence of all traces in the coal itself of the larger parts of arborescent plants, and for their equally remarkable abundance in a broken and dispersed state in the overlying strata.

Assuming such to have been the condition of the surface during the tranquil periods of the accumulation of each coal-bed, we may conceive the other strata to have been produced in the following manner. Let us suppose an earthquake, possessing the characteristic undulatory movement of the crust, in which I believe all earthquakes essentially to consist, suddenly to have disturbed the level of the wide peat-morasses and adjoining flat tracts of forest on the one side, and the shallow sea on the other. The ocean, as usual in earthquakes, would drain off its waters for a moment from the great Stigmaria marsh, and from all the swampy forests which skirted it, and, by its recession, stir up the muddy soil, and drift away the fronds, twigs, and smaller plants, and spread these and the mud broadly over the surface of the bog. In this way may have been formed the laminated slates, so full of fragmentary leaves and twigs, which generally compose the immediate covering of the coal-beds. Presently, however, the sea would roll in with impetuous force, and, reaching the fast land, prostrate everything before it. Almost the entire forest would be uprooted, and

---

[*] Bowman, in "Proceedings of Geological Society, London," No. 69.

[†] Anniversary Address to Geological Society, 1841.

borne off on its tremendous surf. Spreading far inland, compared with its accustomed shore, it would wash up the soil, and abrade whatever fragmentary materials lay in its path, and, loaded with these, it would then rush out again, with irresistible violence, towards its deeper bed, strewing the products of the land in a coarse promiscuous stratum, imbedding the fragments of the broken and disordered trees. Alternately swelling and retiring with a suddenness and energy far surpassing that of any tide, and maintained probably in this state of tempestuous oscillation by fresh heavings of the crust, the waters would go on spreading a succession of coarser or finer strata, and entombing at each inundation a new portion of the floating forest. Upon the dying away of the earthquake undulations, the sea, once more restored to tranquillity, would hold in suspension at last only the most finely-subdivided sedimentary matter, and the most buoyant of the uptorn vegetation—that is to say, the argillaceous particles of the fire-clay—and the naturally floating stems of the plants. These would at last precipitate themselves together by a slow subsidence, and form a uniform deposit, exhibiting but few traces of any active horizontal currents, such as would arise from a drifting into the sea from rivers. The chief portion of the coarser fire-clay would settle first, and then the more impalpable particles, in company with the stems and leaves of the uprooted vegetation. Thus we may account for the constant reproduction of the peculiar soil of the coal-seams, and for the preservation, particularly in its upper clayey layers, of the Stigmaria (Sigillaria); the simple consequence of the final subsidence of these materials being the production of the necessary substratum of another coal-marsh. The marine savannahs becoming again clothed with their matting of vegetation, and fringed on the side towards the land with wet forests of arborescent Ferns and other trees, all the essential conditions and changes that constituted this wonderful cycle in the statical and dynamic processes belonging to each seam of coal, and the beds enclosing it, would be completed, and ready to be once more renewed.

Though the train of actions here imagined enables us to reconcile the indications afforded by the coal-beds of periods of prolonged tranquillity, with the evidences of violent aqueous currents, as shown in the composition of the coarser mechanical rocks; yet a complete theory of the coal-formation calls for the introduction of other considerations connected with the existence and positions of strata derived from chemical and organic agencies, as the limestones, cherts, and beds of carbonate of iron. The analysis already given of our Appalachian Coal-measures will be seen to imply a slow general subsidence, alternating with occasional and less-prolonged movements of elevation, and these gentle changes of level interrupted by sudden or paroxysmal heavings of the crust. Mr Beaumont was the first, I believe, to suggest a subsidence of the land during the progress of the coal-formation; he supposes the coal-beds to be the result of a "luxuriant vegetation, covering swampy islands, which, by the settling down of the disturbed crust of the earth, were covered over with drifted sand, clay, &c." Subsequently Sir Charles Lyell, in an early edition of his *Elements of Geology*, proposed a somewhat similar view. He says, "If the superposition, on a great scale, of purely marine strata to others containing coal and fresh-water shells, leads us to infer that large areas, once constituting estuaries, deltas, and marshes, sank down and became sea during the carboniferous period, so are there reasons for concluding that in many cases the depression of the ground took place gradually, and that, in consequence of the deposition of sediment, the same space was again and again converted into land, and laid under water." In another passage he suggests, that "if we appreciate the full strength of the evidence in favour of continued subsidence in the coal-field of South Wales, we shall be the less surprised to learn that the vertical depth of the superimposed strata is enormous, amounting in some places to no less than twelve thousand feet."* Though a vast perponderance of subsidence over elevation is plainly indicated in the prodigious thickness of the Coal-measures, each particular coal-seam in which, was produced successively at the surface, I cannot conceive that either an alternation of periods of subsidence and repose, or an uninterruped prolonged depression, will explain the phenomena of the Appalachian coal-rocks, as they have been here described. A general subsidence, throughout the coal period, of all the great area now occupied by the Appalachian basins, is proved, independently of the above evidence derived from the nature of the coal-beds, by the interesting fact, that the lower seams of Ohio and Western Pennsylvania have their E. limit more than 150 miles to the W. of the general E. boundary of the upper ones; and as we ascend in the formation, the beds extend successively more and more to the E., or in the direction of the ancient land. But considering the many striking instances which I have recorded of the close approach or actual contact of certain beds of coal and oceanic limestone, we cannot resist the conclusion, that the gradual downward movement was frequently interrupted by a slow upward one. In all the instances that I have cited, where the limestone stratum immediately underlies a coal-seam, it is obvious that an upward movement of the land must have taken place, so gradually as to be unattended by any sensible commotion of the waters. A considerable and sudden lifting of the bed of the sea would infallibly have caused the production of violent currents, competent to spread over the quiet precipitate of limestone, one or more coarse arenaceous or argillo-arenaceous strata. That the intervals of repose indicated by the limestones were, like those of the beds of coal, sometimes suddenly terminated by earthquake disturbances, strewing over the marine sediments the materials of the land, is manifest from the phenomena, though it is not less clear that the cessation of the periods of relative tranquillity, marked by very gradual subsidence, must in all cases, where the coal-beds are overlaid directly by marine limestones, have been effected by simply a more rapid process of depression. Every superimposed limestone, without an intervening roof-slate or sandstone to separate it from the coal, affords, I conceive, a conclusive proof of this increased rate of submergence. Perhaps it will be objected, that a merely accelerated subsidence, such as I have here supposed, if taken in conjunction with the hypothesis of a drifting of the land-materials by rivers, will satisfactorily explain all the facts which I have ascribed to the turbulent movement of the sea against the land during earthquakes. But though it is highly probable, from the phenomena of nearly every extensive coal-field, that rivers did carry into the parts of the ocean and its estuaries, now drained and occupied by the coal strata, a considerable quantity of argillaceous deltal deposits, yet it is difficult to imagine how any moderately rapid subsidence, if unaccompanied by some *paroxysmal* movement, could create a current energetic enough to uproot and float away nearly the whole of those vast forests, which evidently grew close to the site of each seam of coal, and to snap off to the stumps even the most colossal trees. Nor is it easy to explain why such a quiet submersion of the swampy forests did not result in the preservation of the trees in their original erect posture, by the drifting around them of the supposed river sediments. It is fair to infer, that so long a line of coast as we must conceive bordered the Appalachian ocean, if we may judge from the great longitudinal extent of some of our coal-seams, was not destitute of rivers, and we are therefore constrained to admit that some amount of sedimentary matter must have entered the sea in that manner ; but at the same time, we have only to notice the striking deficiency of earthy matter in the numerous coal-beds, and in many of the strata of limestone, to be persuaded that the amount of material contributed to the Coal-measures by fluviatile transport was relatively inconsiderable. It may be fairly questioned, whether any sensible proportion of river silt could spread itself to the distance of 150 or 200 miles seawards, over the great coal-morasses of such a coast ; and yet we are compelled to assume this, if we deny the above paroxysmal theory.

---

* LYELL's *Elements*, Boston edition, vol. ii. pp. 128, 134.

That the geological and geographical changes known to have been caused in modern times by earthquakes, entitle us to speculate upon their agency in suddenly shifting the level of the low tracts once occupied by the marshes and swamps of the coal-seams, must, I think, be conceded. Few geologists will deny the probability of frequent changes, in the carboniferous period, analogous to that which took place in the great plain at the mouth of the Indus in the year 1819. It is mentioned in Lyell's *Elements*, that " extensive flats bordering the Indus sank down, and, for many years after, vessels were forced through the boughs of the tamarisk trees, still standing erect." *

Should the foregoing theory, based on the complicated statical and dynamic phenomena of the Appalachian coal strata, be correct, then have we, in every stratum of the series, not merely a new picture of the physical geography of the region, but a clear legible record of the very changes, gradual or tempestuous, of which each in its turn was the result. We unclasp, as it were, a whole volume of hydrographic charts, displaying, for a vast succession of epochs, the ever-changing relations of the land and waters. A wide tract of ancient coast is at one time occupied by the ocean, at another by an immense plain filled with green marshes and swamps, and at another by dry land clothed with a tangled forest. But we behold more than merely these several conditions of the surface : we perceive the very transitions themselves which revolutionised the geography ; we discern the ocean in the very act of encroaching on the land, forming extensive marshes where before the whole was solid shore ; we actually trace it in its gradual retreat, exposing its own marine sediments to form a fertile soil for vast savannahs, and again we see the entire region embracing the dry land, the marshes, and the sea, heaving and undulating in the billows of the irresistible earthquake, the ocean and the land contending for mastery in the tremendous conflict.

If the Appalachian coal strata, whose history I have here endeavoured to interpret, exhibit truly the above-imagined conditions and events, we may consider the entire formation as constituting a stupendous tide-gage, registering the lengthened ebbings and flowings of that ancient sea, and the stormy agitations of its oscillating waters, as the epoch of its last greatest movement and final drainage drew near.

GRADATION IN THE PROPORTION OF VOLATILE MATTER IN THE COAL OF THE APPALACHIAN BASINS.

There prevails a very interesting law of gradation, in the quantity of volatile matter belonging to the coal, as we cross the Appalachian basins from the S.E. towards the N.W. The extraordinary extent of area over which this law obtains, and its intimate connection with corresponding gradations in the structural phenomena of the region, the description and theory of which have been given elsewhere by Professor W. B. Rogers and myself, seem to claim for it a place in the present general account of our coal-measures. The gradation may be thus briefly described :—Crossing the Appalachian coal-fields, N.W. from the great valley to the middle of the main or W. trough, by any section between the N.E. termination of the formation in Pennsylvania and the latitude of Tennessee, we find, as the result of multiplied chemical analyses, a progressive increase in the proportion of the volatile matter, passing from a nearly total deficiency of it in the driest anthracites, to an ample abundance in the richest gaseous coals. The existence of this singular law of transition was first ascertained by me in 1837, in which year I made mention of it in some public lectures. It was communicated to the Association of American Geologists, at their first annual meeting, in the spring of 1840 ; but I did not publish it in print until the following winter, when it was briefly alluded to in my Fifth Annual Report on the Geological Survey of Pennsylvania. Evidence of the existence of such a gradation in the coals of Western Virginia will be found in the annual reports of the Geological Survey of that State for the years 1839 and 1840. These historical references are here introduced, because the determination of the general fact was the result of many laborious analyses of our coals, made by my brother and myself, and because attempts have been made by others to establish a claim to the discovery. The lists of analyses contained in the Reports of the Surveys of Pennsylvania and Virginia, and similar data not yet published, show the following as the general proportion of the bituminous matter in the different belts of the formation, as we cross the region from S.E. to N.W.

---

* Lyell's *Elements*, vol. ii. p. 136.

First, In the most S.E. chain of basins the coal is, for the most part, a genuine anthracite, containing, however, sometimes a small per-centage of bitumen, and always a little gaseous matter, chiefly hydrogen. The quantity of the volatile matter varies, according to geological locality, from about six to twelve or fourteen per cent. This first belt of basins embraces all the anthracite coal-fields of Pennsylvania, the slightly bituminous ones of Broad Top on the Juniata, of Sleepy Creek, of the Little North Mountain, of Catawba Creek, Tom's Creek, Strouble's Run, and Brushy Ridge, in Virginia. The coal of the Little North Mountain is, however, a true anthracite. All of these coal-fields, and insulated patches of the formation, belong to the most disturbed portions of the Appalachian chain, and they are associated with some of the boldest flexures and greatest dislocations of the whole region. The first or S.E. anthracite basin of Pennsylvania presents innumerable sharp flexures and close plications, with inversion, of the strata.

Secondly, In the next well-defined range of basins farther towards the N.W.—that, namely, of the Alleghany Mountain, and the general escarpment of which it is a part—the proportion of volatile matter varies usually from sixteen to twenty-two per cent, but is generally about eighteen or twenty per cent. This belt includes all the coal-fields situated immediately to the N.W. of the Alleghany Mountain in Pennsylvania, also the Potomac basin, in nearly the same line, and the coal-fields of the Little Sewell, and the E. side of the Big Sewell Mountain in Virginia. The position of this belt of the Coal-measures is somewhat W. of the region of steep flexures of the strata, and beyond all the considerable dislocations, while it embraces a few very extensive, regular, and nearly symmetrical anticlinal axes of the flatter form, distinctive of their intermediate position between the E. and W.

Thirdly, The great Appalachian basin, with its subordinate troughs, forming the wide coal-field watered by the Ohio River and its tributaries, embraces a series of coal-beds, which are all distinguished by a still larger amount of volatile matter. In crossing the breadth of this wide coal-field, we find a very material alteration in the character and composition of the coal. Along its E. side, or near the last considerable axis of the Appalachian chain, the amount of volatile matter is commonly from thirty to thirty-five per cent. Westward of this line, on the Monongahela River, both in Pennsylvania and Virginia, the proportion approaches to forty per cent; while still farther in the same direction, or near the Ohio River, it ranges from forty to even fifty per cent, according to local circumstances. In this most Western or main coal-field, the flexures of the strata are extremely gentle, and comparatively wide apart; but even here we observe a beautiful progression in the amount of the bitumen, as we recede from the very low axes which traverse the S.E. side of the great plain. What renders the foregoing comparison of the several ranges of the coal-formation particularly exact and satisfactory, is the circumstance that, in more than one instance, we are enabled to trace the very same coal-seam, through its various degrees of bituminisation, from an almost true anthracite to a form in which it possesses a full proportion of volatile matter. Thus the great Pittsburg Bed, to take it as an example, contains on the Potomac, in some localities, as little as 15.5 per cent; but near the Eastern margin of the great Western basin, as at Blairsville, and again in Virginia, it has about thirty-one per cent; and towards the middle of the main basin at Pittsburg and on the Kenawha, as much as from forty to forty-three per cent.

The cause of the different degrees of de-bituminisation of the coals, in different parts of their range, I am disposed to attribute to the prodigious quantity of intensely-heated steam and gaseous matter emitted through the crust of the earth, by the almost infinite number of cracks and crevices which must have been produced during the undulation and permanent bending of the strata. All the phenomena of modern earthquakes and volcanoes warrant us in supposing that the elevation of our coal-rocks, if effected in the manner I have imagined, must have been accompanied by the escape of an immense amount of hot vapours, the chemical and thermal agency of which cannot be overlooked, upon any hypothesis of the rending and uplifting of great mountain-tracts. It is easy to conceive that the coal, throughout all the E. basins, if thus effectually steamed, and raised in temperature in every part of its mass, would discharge a greater or less proportion of its bitumen and other volatile constituents, as the strata were more or less frequently and violently undulated by earthquake action. It is also obvious that the more Western beds, remoter from the region of active movements, less crushed and fissured, and presenting a greater resistance to permeation by the subterranean vapours, would, in virtue of their mere geographical position in the chain, be much less extensively de-bituminised. The striking fact that we nowhere, not even in the most dislocated and disturbed districts of the anthracite coal-field, find any traces of true igneous rocks, that, by their contiguity to the coal, could have caused the loss of its bitumen, is a circumstance in their geology which goes far to confirm the truth of the hypothesis. Precisely in proportion as the flexures of the strata diminish in our progress W., does the quantity of the bitumen in the coal augment; but it is difficult to conceive how any such law of gradation could have been the result of a temperature transmitted by conduction from the general lava mass beneath the crust, for that would imply a corresponding increasing gradation in the thickness of the crust, advancing W. under the coal-fields; whereas such an inference is in direct conflict with the fact of the general diminution W. of the Appalachian rocks, besides being inconsistent with all correct geothermal considerations, which forbid our imagining so unequal a conduction, to the surface, of the earth's interior temperature.

FOSSILS OF THE COAL-FORMATION.

Without attempting here a full enumeration of the organic remains of the Appalachian Coal-measures, it is essential that we examine into the nature of those which may assist us to explain the physical conditions under which the different materials of the formation were produced.

The vegetable remains nearly all imply a humid climate, and a growth in a wet or marshy soil. The predominant plants of this wide coal-field, as of all the other chief coal-fields of the world, appear to be *Ferns*, some of them herbaceous, some arborescent. Their stems and fronds are very seldom to be met with either in the under-clays of the coal-beds or in those shales which are nearest allied to these under-clays in their composition. On the other hand, they abound in the strata which by their lamination imply deposition from gentle currents, such as the argillaceous sandstones, but especially the dark carbonaceous slates and shales, which in many instances immediately overlie the coal-seams, or are imbedded in them. The perfectly smooth or unrumpled condition in which so many of the fern-leaves, even to their most delicate and silky leaflets, are preserved between the laminæ of the slates, indicates that they cannot have been borne along by turbulent currents, but must have floated tranquilly in nearly still water, until they became imbedded in soft sediment on a quiet bottom.

Another abundant fossil is the *Lepidodendron*, a genus of which more than fifty species are already known to palæontologists. Of these, several kinds occur in the Appalachian coal-fields, their beautifully-marked stems being found in a more or less mutilated and crushed state in the coarser rocks, especially the sandstones, but sometimes also in the argillaceous beds, and even in the laminæ of the coal itself, in which, and in the black slates adjoining the coal-beds, we often meet with the slender grass-like leaves ascribed by botanists to this class of plants. In Pennsylvania the remains of Lepidodendra appear on the whole to be more abundant in the lower Coal-measures than in the upper, while the reverse of this is true of the ferns. This curious tribe, supposed to belong to the order *Lycopodiaceæ*, and to be represented by the living club-mosses abundant in tropical climates, was evidently one of the chief coal-producing plants of the Carboniferous era. Their huge flattened stems lie imbedded in the roof-slates of the coal-beds, or impressed between the laminæ of the coal itself, in a manner which suggests that they grew in a matted or tangled manner upon the surfaces of the broad wet plains in which the coal was formed. It is probable, indeed, from their great abundance, and their supposed capacity for taking root wherever the stem touched the soil, that they constituted a predominant feature in the vegetable landscape of the wide coal-producing savannahs, where this gigantic cryptogam played the part of the moss or sphagnum of the peat-bogs of the present day. The frequent occurrence of crushed and broken stems of Lepidodendron in the coarser rocks of the Coal-measures, especially in those which directly overlie the beds of coal, would seem to intimate that this plant was particularly susceptible of being torn or floated away by the currents which overspread the coal-meadows with the sandy and other detrital matter of these rocks.

Of equal importance with the Ferns and Lepidodendra is the plant called *Sigillaria*. This is a tree-like fossil, of cryptogamic structure, it is believed, but of somewhat higher organisation than any flowerless plant at present in existence. In the structure of some of its vessels it closely resembles the Ferns, to which it, moreover, bears some affinity in the scars left by the leaf-stalks upon the surface of the stem It deviates from the Ferns and other Cryptogamia, however, in displaying slender linear leaves. Of the genus there are at present more than forty-five species known to botanists. Some new ones, from the anthracite coal-fields, are figured on Plates XV. and XVI. of this work. Though allied to living plants of humbler stature, the Sigillaria, in some of its species, grew to a stalwart height and bulk. Their stems, which appear to have been regularly cylindrical, and destitute of branches, have been seen from 1 to 5 feet in diameter, and from 40 to 70 feet long. We remember one, visible in a compressed and flattened state, in the roof-slate of the coal at Carbondale, which had a length of more than 50 feet, and a diameter of 2 feet at its broader end. Colossal as this genus of plants was, it appears to have possessed a mode of growth of only the more lowly organised plants of the present day; for, in addition to the features already described, it subdivided towards its top by simply forking, not by throwing off true branches. The stem, moreover, appears to have consisted largely of soft cellular tissue, in virtue of which it was very easily prostrated, and very compressible when thrown down; and hence we so rarely find this fossil standing erect in the strata, but generally see it in a squeezed and flattened form, imbedded between the strata, and its interior or even the entire mass filled with, or converted into, the material of the rock which encloses it. But the most remarkable discovery connected with Sigillaria is the finding *Stigmaria* connected with it as its roots—a relation which has cast a flood of light on the whole theory of the origin of coal. This fossil (the Stigmaria), as already intimated, was at one time regarded as an independent plant, and was supposed to be the chief plant concerned in the production of the coal; but the eminent French botanist, M. Brongniart, guided by certain analogies of structure between Sigillaria and Stigmaria, shrewdly suggested that they might be respectively merely the stem and root of the same organism; and this astute scientific inference was soon afterwards (about the year 1846) amply corroborated by the almost simultaneous discovery, in Great Britain and Nova Scotia, of the physical connection of the two fossils. Several stumps of Sigillaria were detected by Mr Binney in a railway-cutting terminating downwards in well-formed roots, identical with Stigmaria, the Stigmaria resting in a coal-seam, and the stump or trunk enclosed in an overlying bed of sandstone. Soon afterwards, Professor Dawson found near Cape Malagash, in Nova Scotia, an instance of the same connection, which was nearly as conclusive.* Later in the same year, Mr Robert Brown, of Sidney, discovered still more perfect and convincing instances of erect Sigillaria, terminating in Stigmaria as roots, in the coal-strata near Sidney. As these and other instances have been already cited in my account of the Nova Scotian coal-fields, I need not multiply examples of this important fact.

Various other forms of vegetation, common in the coal-fields of Europe, are to be met with throughout nearly every part of the wide Appalachian basin and its outlying troughs; but as these are less essential to the theory of the origin of the Coal-measures than the preceding, I shall pass them over with the bare mention of their names. The genus *Calamites* is one of them, existing in several species: these fossil plants, once regarded as allied to the existing Horse-tails or common Equiseta, but in gigantic proportions, have been pronounced by Brongniart as of probably higher structure than any of the flowerless plants. He has indeed brought them under a new genus *Calamodendron*, which is now regarded as an internal pith of a larger plant; its place in the vegetable kingdom is very imperfectly understood. Asterophylites is another coal-plant frequently found in our coal-slates.

The sandstones of the Coal-measures not unfrequently exhibit fossilised stems of what seem to be coniferous trees; these, and the other tree-like stems, as they are seen in the Appalachian coal-fields, almost invariably lean at a low angle in the thick sandstone strata which enclose them; they seldom occur in the shales, but are nearly restricted to those coarser rocks which appear to have been deposited by rapidly-flowing currents. It is not a little curious that nearly all of these trunks dip towards an opposite quarter from that towards which the false bedding or oblique lamination of the surrounding sandstone itself declines. This fact, noticed by me not merely in Pennsylvania, and on the Ohio River above Gallipolis, but also in the instance of the celebrated Craigleith tree near Edinburgh, and in the great tree of the Granton quarry, near the Firth of Forth, goes far, I think, to demonstrate that all these leaning stems have been imbedded in the manner of *snags* in actively-moving currents, their butt-ends settling first, and their lighter tops pressed forward by the waters, which at the same time piled the sand obliquely about them with a forward dip.

OF THE FORMATIVE ACTIONS CONCERNED IN THE PRODUCTION OF THE PALÆOZOIC AND OTHER STRATA.

Geology recognises four classes of actions in the production of the stratified envelope or outer crust of the globe: 1*st*. Igneous action, or the effusion of mineral matter in a melted state; 2*d*, Vital action, or the production of organic forms by vital secretion of the elements; 3*d*, Chemical action, or precipitation of matter in a solid form from aqueous solution; and 4*th*, Mechanical action, or the strewing of mineral fragments, or particles already solid, by the waters—and in a less extent by the winds, in more or less active motion. It is chiefly of the last function, or that of stratification by moving water, that I propose to treat in this place.

The essential dynamic conditions of sedimentation by water, are, first, the force of terrestrial gravitation acting perpendicularly upon suspended or floating matter; secondly, the approximately horizontal force of moving water exerted either continuously or intermittently; and, thirdly, the resisting force of friction, operating between the strewn matter and the floor over which it is propelled, and between fragment and fragment of the moving material itself.

Water will deposit or let go solid particles suspended or floating in it at all angles of subsidence, from a nearly perpendicular one, when it is in a state of almost absolute repose, to an approximately horizontal one, when its velocity is very great in comparison to the sinking tendency of the material it floats. This latter element, called buoyancy, is itself dependent upon the specific gravity and the degree of comminution of the suspended particles; for the degree of comminution measures by a certain law the ratio of surface, and therefore of resistance, through friction, to the force tending to sustain the weight or downward tendency.

---

* Proceedings of the Geological Society of London, for January 1846.

Perpendicular Deposition.—In the case of water nearly at rest, the conditions of precipitation of suspended matter heavier than itself, either chemically or mechanically derived, are extremely simple. The subsidence is nearly perpendicular, only varying in slowness as the solid matter is more or less buoyant, and in depth of accumulation as the time is more or less protracted, and the amount of matter in suspension more or less abundant. Strata thus produced are remarkably uniform in their thickness, and constant in their composition and degree of fineness, are free from lamination, and are very massively bedded. Where the sedimentary matter is impalpably fine, and the water in nearly absolute repose, a true stratification or division into layers scarcely takes place, for this requires either some interruption of action, change of material, or partial horizontality of movement. On the other hand, the entire mass is of the nature of a homogeneous pulp without horizontal divisional planes or partings. Instances of this mode of deposition are not infrequent in nature, and the processes of the industrial arts furnish abundant instances of it, for example, in the pulpy magmas of the precipitating vats of every large chemical work. But deposition without stratification may and does occur, where the fragmentary matter is coarse and heterogeneous, as when a torrent or surge of water sweeps or pushes a body of coarse gravel and sand into dead water, or into an opposing current, capable of producing at their line of mingling a local and temporary cessation of the onward motion. I conceive that the unstratified Till of the Boulder-drift has been simply a deposition under these circumstances. The drift-conveying current has encountered a check from some rebounding wave or oscillating pulsation of the ground over which it has been rushing, has reached a pause in certain places long enough for a perpendicular heaping together of its promiscuous materials, without the onward motion necessary to laminate them.

Stratification, or Deposition with Strewing, by Water in Motion.—The formative or reproductive function of moving water deserves, I conceive, a far more careful study than it has hitherto received from geologists. Through inattention to some phases of the action, the gravest mistakes of theory are constantly committed, and even serious misestimates made respecting the depths and dimensions of formations.

We may view water in motion as possessing two modes of transportation: it can drive before it a mass of fragmentary mineral matter, too coarse or heavy to be actually suspended in it, propelling it against much mutual attrition, and the retarding friction of the ground, with a rolling motion, until it spreads it in a broad sheet upon the surface which itself previously occupied; or it can hold the sedimentary matter in a state of suspension, and waft it onward, gradually depositing it as it flows.

Stratification without Suspension.—Inasmuch as nearly all rocky substances lose almost two-fifths of their weight when immersed in water, it is obvious that the rolling material, being so much lighter than in air, encounters so much the less impediment to its progress from resistance by the bottom, and by mutual friction of its lumps and particles. This mode of strewing of the loose debris of the land produces necessarily an obliquity in its bedding, precisely as when a rake or harrow is propelled over movable earth or gravel to smooth it down; the surface will be even, and approximately horizontal, while the mass will be formed of forward-dipping layers, successively and slantingly deposited. As the action in such cases is necessarily more or less paroxysmal or intermittent, there will arise in this mode of dispersion much re-strewing of the upper exposed portions of the already deposited sediments. If the movement of the water is energetic, the outward-pushing current will be followed by a pause, and this by a rebounding or shoreward motion; and the result of this change will be the deposition of a horizontal layer upon the previously-formed inclined ones, and immediately upon the top of this a second series of obliquely-bedded strata dipping towards the land; and this cycle of oblique and horizontal bedding may be repeated several times before the waters return to rest, or assume a permanent current-movement. In many instances, the second push of the waters, especially in the outward direction, will be strong enough to sweep up and re-disperse a part of the matter previously laid down, and thus the lower sheet will have its beds shaved down or truncated, and a new series of layers superposed upon them, either dipping to the same or opposite quarters. It is not necessary to the production of this oblique or cross-bedding that the surface or floor strewn by the deposit should be beneath the permanent or tranquil level of the sea or other recipient basin, nor is it at all essential that the floor should slant. Every one who has carefully examined the detrital matter left by a

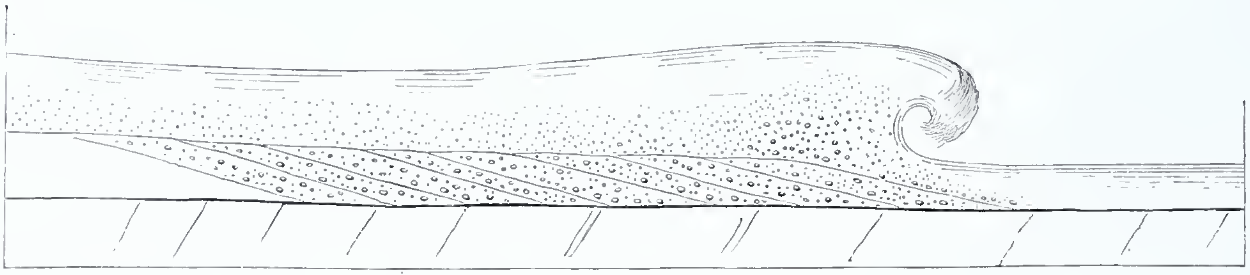


FIG. 587.—Oblique Deposition by Strewing.

violent wave or torrent that may have suddenly swept over the dry land, as when a great river-dam gives way, must have noticed that the materials which it pushed before it, even upon slightly-ascending ground, were thus slopingly laid down. Indeed it is obvious that any heavy surge of water, rushing across an upland tract, will, as long as it retains a high velocity, and meets with a supply of loose fragments, or with strata which it can abrade, necessarily deposit its rolling dregs in this forward-tilted posture. It is literally a case of *smearing* on a grand scale, the advancing front of water, or most actively-moving wave within it, being the knife edge; and as in all examples of this mode of distribution of plastic matter, the front, being resisted below and propelled above, takes on the sloping attitude.

In the mensuration of the strata, thus slantingly deposited, great errors may be committed, whether the bed retains their original posture or are uplifted by a subsequent movement of the crust; as will appear, if we consider the amount of discrepancy which exists between the actual thicknesses of the strata, measured from one horizontally original layer to another, and their calculated thickness, as compiled from the diameters of the oblique divisions of which they consist. And when the originally horizontal partings are wanting, or obscurely traceable, the difficulty of avoiding this error from obliquity is very great, and vitiates many patient measurements. This source of error insinuates itself, in fact, into all trigonometrical estimates of strata, where the distances across their outcrops are comparatively great, or exceed by many times the spaces between the main divisions of the formation; for, as I shall presently show, *all mechanically-derived deposits are obliquely bedded upon one another on a greater or less scale.*

Stratification from a State of Suspension in Water.—In all instances where the relation of the velocity of the water to the bulk of the particles or fragments—or, in other words, their buoyancy—is such as to keep them from reaching the bottom for a shorter or longer distance from the shore or permanent water-line, the stratum which they form, whatever may be its horizontal dimensions, will exhibit a thin edge towards the land, gradually thicken as it recedes, and then still more gradually attenuate till it ceases. This arises from the floating and rolling matter coming to rest only as the velocity of the current declines, from the precipitation increasing as the retardation proceeds, and from the materials becoming ultimately exhausted. It is obvious that between the two limits of too high a velocity and a low supply of slowly-falling particles, there must exist a space where the two conditions of lessening speed, and repletion of material, are together at a maximum. Every stratum—every formation, indeed, however wide—which is the product of one formative transporting current, even though its deposition may have occupied many ages, possesses this tapering-off towards both its landward and seaward margins; in other words, its cross section is fusiform. But while it displays this attenuation in both directions, its component fragments, whether boulders, pebbles, grains of sand, or particles of clay, will, in the aggregate, show a steadily lessening size from the inner to the outer edge of the deposit; and wherever we meet with exceptions to such a progressive declension in their coarseness in a given direction, we may be sure that some change arose in the velocity, or in the course of the current; and when the change is conspicuous, we are to regard the deposit as marking another and different formative stage.

Now it should be observed that all depositions of land-derived mineral substance must take place on shelving bottoms, and the sediments themselves must form a succession of gently-inclined planes. Absolute horizontality can scarcely arise, nor can there be a near approximation to it, except in tracts far removed from the shore, and where the currents are very gentle, steady, and long-continued. Thus, then, the feature of oblique bedding, or the successive overlapping of slanting deposits from original obliquity of deposition, is a primary fact of all mechanical strata. It is obvious that if the members of a formation, thus slopingly accumulated upon a bottom more horizontal than themselves, be measured for thickness by the usual trigonometrical process of taking their angles of dip, and the breadth of their outcrops, we shall be liable in many cases to commit the grossest exaggeration in our estimate of their total depth or thickness. As a general rule, the difference between their actual and their calculated mass will be greater, the greater the length of our section, other things remaining constant; for the greater the breadth of outcrop, the more room is there for the thinning out and coming in of deposits, nowhere to be found vertically superposed. I think it will be found, too, that conglomerates and coarse sandstones, by tapering more rapidly in their dimensions than the finer argillaceous strata, will be the most subject to over-estimation.

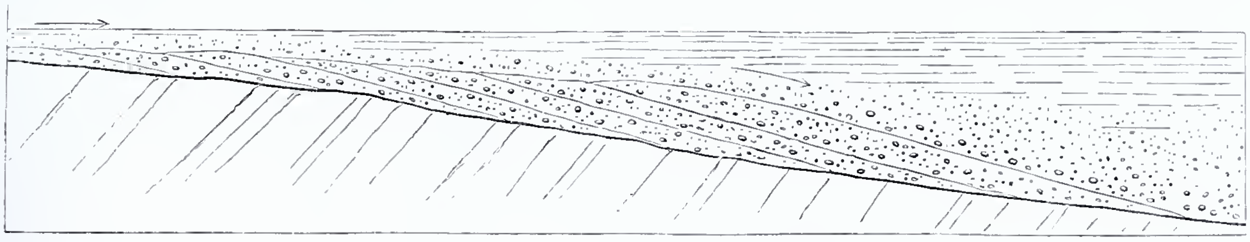


FIG. 588.—Oblique Stratification from Suspension.

From the considerations here presented, it seems highly probable that the astonishing thicknesses recorded by geologists of many mechanically-formed deposits—for instance, the Coal-measures of South Wales, computed at

9000 feet, and those of the Joggings in Nova Scotia, estimated at 14,000 feet; or again, the Old Red Sandstone of Scotland, calculated at 5000 feet—are all egregiously too great for Nature. The serious detriment to scientific and practical geology of an habitual over-estimate of the depth of the several formations, more particularly the Carboniferous, needs no comment. In computing the spaces which separate the seams of coal in a group of Coal-measures, I have long ceased to place any reliance upon trigonometrical measurements of the included coarser mechanical rocks. Where the strata outcrop at angles sufficiently steep to admit of direct measurements from coal to coal, either perpendicularly to these beds—the surest of all guides—or on a horizontal surface across a narrow interval, very little error need creep in; and there is an equal correctness where the stratification of the coal-field is approximately horizontal, and we measure perpendicularly through all the rocks intersecting coal after coal.

Perhaps the most remarkable example of original obliquity of deposition, on an extended scale, to be met with anywhere, is that which is presented by the Mesozoic red sandstone of the Atlantic slope in the Middle States. This formation exhibits, in New Jersey and Pennsylvania, a width in many places of more than 25 miles, yet it displays but one direction of dip, or one series of original planes of sedimentation, throughout this entire space. The slope of the beds is everywhere N., and at angles varying from 10° to 30°. Now, if computed trigonometrically, this formation should possess a depth of many miles; yet there is the amplest evidence in the physical geography of the region and, above all, in the exposure by denudation, of the floor upon which it rests, that it is *extremely shallow*. In the neighbourhood of New Hope, some 13 miles from its S. margin, where the formation should have, by the usual rule of estimation, a depth of not less than 10,000 or 12,000 feet, its bottom is actually exposed, and its thickness is not more than 50 feet. It was deposited, in truth, in a wide shallow estuary or tidal bay, ascending S.W. into a broad shallow river, but its materials were swept in from the S. and S.E. *across* its channel, which evidently lay next its N.W. shore, and were slantingly laid down, the whole process assisted probably by a gradual lifting out from beneath the water of its S.E. coast, accompanied by a rising of the land in that direction.

Having discussed as succinctly as possible the mechanical conditions of the sediments, coarse and fine, upon a stationary floor, I might, if space permitted, consider with profit the effects on stratification upon a great scale, produced by movements of the crust, or shiftings of level of the land and sea, both secular, or gradual and prolonged, and paroxysmal, or sudden and violent. Even in the now existing comparatively quiescent state of the earth's crust, the relative level of the ocean, and the lands confining it, remains nowhere absolutely constant, but is ever slowly shifting, secularly or paroxysmally, or in both modes combined. In some regions it is with elevation, in others with permanent subsidence of the land. But these changes must have been both more extensive vertically and more rapid in the ancient periods, when the earth's crust was manifestly more flexible. Let us take a glimpse of some of the more obvious results of these grand mutations of level.

1. Wide tracts of coast, including the shelving bed of the adjoining sea, are liable, and have been in all geological ages, to a general equably-distributed uprising and subsidence. If, while deposition is steadily proceeding, the watery floor receiving it is either gradually or by sudden shocks permanently lifted by a self-parallel movement, it is plain that, throughout the space thus shifted in level, the sediments formed at successive stages must be more and more restricted in their horizontal limits. Each later sea-margin will lie somewhat more seaward than its predecessor, while the opposite or seaward edge of the deposit will overlap or lie beyond in the same direction. Thus we see that no two successive parts of a formation so produced will be strictly superposed, but will lie like a pile of paper whose leaves have slipped a little obliquely on each other. The stratification of the great Appalachian coal-field offers, I think, some interesting exemplifications, hereafter to be adverted to, of this important feature of the under and over-lapping of the original edges of parallel beds.

2. If, on the other hand, the coast and adjacent sea-bottom gradually or intermittently sinks with a self-parallel movement, the successive sheets of sediment will encroach landwards, and both their margins will shift from the previous area of the water towards that of the land. Here the overlapping will be next the land-side, each later deposit having its margin farther in.

The views now presented apply not merely to sediments produced on the level of the sea, or on a water-covered floor, but equally to accumulations, limited by physical conditions, only prevailing at the water-side. They apply, in other words, as well to the terrestrially-formed beds of coal as to the more purely aqueous deposits of shale and sandstone which commonly enclose them. Every coal-seam was once a wide level peaty meadow or morass, resting at or very little above the sea-level, or the level of some broad sheet of water; and its accumulation, from a redundancy of vegetable life, depended upon a nice adjustment of the conditions of humidity and dryness. The extension of this vegetation must have been restricted, on the side towards the water, by an excess of moisture, on the land side by a deficiency; for we are sufficiently familiar with the structure of the coal-producing plants to know that, while they could not have grown entirely immersed in water, they could as little have flourished upon an upland-rolling surface, where their roots and lower stems could not be kept constantly moist.

Other modes of fluctuation of level of land and sea, introducing their own special conditions of stratification and superposition of sediments, present themselves to our notice. Such are chiefly—1. A secular or paroxysmal rising of the land, and adjoining sea-bottom—the ocean remaining always stationary,—with broad undulation; and, 2. A depression of a coast, and the contiguous watery floor, with a similar departure from self-parallelism. Each of these modes of alteration of level may be, or rather must be, accompanied by either a greater rapidity in the rising or in the sinking of the shore than of the sea-bottom, or by the reverse—a more rapid rising or sinking of the bed of the sea than of the land. In other words, an unequal rate of subsidence or elevation of a coast, compared with its opposite sea-bed, includes four categories—1. A more rapid lifting of the coast than of the remote watery floor; 2. A more rapid lifting of the latter than of the former; 3. A more rapid sinking of the shore than of the sea-bottom; and, 4. A more rapid sinking of the sea-bottom than of the shore.

With each of these slow or secular movements, there is, and always must have been, associated, but more actively in the earlier geological ages, occasional paroxysmal undulations of the surface; and these long-continued secular sinkings and risings of the land and abrupt paroxysmal ones resulted in permanent low flexures of the crust in great alternate zones. But to enter upon a special analysis of the effects of these several modes of displacement of the relative level of land and water, would take me too far from my present purpose of this essay, which is to discuss only those laws of geological dynamics which possess a direct scientific and practical bearing.

ORGANIC REMAINS OF THE PALÆOZOIC STRATA OF PENNSYLVANIA.

FOSSILS OF THE PRIMAL STRATA.

The only organisms hitherto anywhere discovered in the Primal strata are two or three plants of obscure affinities, a worm-like form called *Scolithus,* one or two molluscs, and a few trilobites of an humble type.

The few vegetable structures seen are, without exception, related to the marine Algæ, or sea-weeds; or, more strictly, they belong to that doubtful group of fossil plants called *Fucoids.*

The best specimens met with in the Geological Survey of Pennsylvania were found in the Primal upper slate of Chiques Ridge at the Susquehanna. The most clearly defined form is not unlike the marine plant, *Fucoides duplex* of Hall, described by him from the Primal sandstone of Lake Superior (see Foster and Whitney's *Lake Superior,* Plate A, 23), though I would by no means affirm that it is the same species.

Of *Animal Remains,* by far the most abundant form is the *Scolithus linearis* (see Fig. 589). This curious fossil, alluded to in the Annual Reports of Virginia and Pennsylvania under the name of *Tubulites,* is a nearly straight cylindrical simple stem-like impression, usually almost smooth, but in some specimens faintly waved or grooved transversely to its axis. Its diameter is from one-eighth to half an inch, its length from a few inches to 2 or 3 feet. Its position in the rock is invariably perpendicular to the bedding, suggesting the idea of perforations by some marine worm. One end of the fossil always terminates at the upper surface of the bed of sandstone enclosing it, and usually in a rudely-flattened knob or head, giving to the whole a likeness to a large long pin. This knob is probably a cast formed in a wide conical funnel-shaped mouth of a cylindrical perforation.

Similar stem-like forms occur in some of the other sandstones of the higher Appalachian formations, but none are so well characterised as this species of the Primal white sandstone. (Our figure represents the corrugations of the surface rather too distinctly.) An excellent locality is Chiques on the Susquehanna.

This fossil occurs in great abundance in the Blue Ridge of Virginia.

The Primal sandstone is also characterised by a species of *Lingula,* the *L. prima* of Conrad, a small obtusely-oval shell, resembling somewhat the *Lingula curta* of the Matinal limestone (which see). Its surface is faintly marked by concentric lines and delicate longitudinal striæ. It is by no means so common as the Scolithus. This shell is not unlike the *Lingula Davisii* of the Lingula flags of North Wales, one of the oldest fossils known in the Palæozoic rocks of Europe.

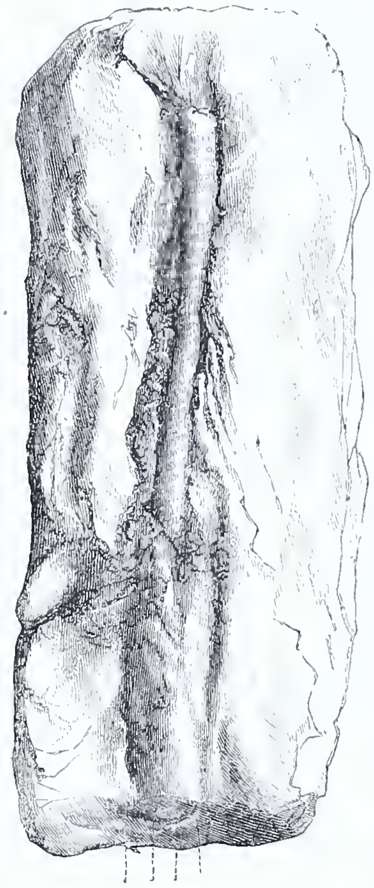


FIG. 589.—Scolithus linearis.

It is not a little curious that these extremely ancient Lingulæ are represented by other species of the same genus in strata of nearly all later geological dates, and by several now living in the existing waters of the globe. The occurrence of the same genus, so little modified through so vast a lapse of geological time, bespeaks a general uniformity in those physical conditions of the ocean affecting the less sensitive forms of life, which is instructive. As, however, the few primoidal species are not identical with any belonging to subsequent ages, we are not entitled to infer that the physical circumstances, especially the conditions of temperature and pressure with which they were in harmony, were at all identical with those of later or present times, for many existing marine genera, and eminently so this genus Lingula, possess species adapted to extremely dissimilar climates and zones of depth in the ocean.

In extent of complexity of organisation, the genus Lingula by no means ranks among the humblest of the Molluscæ.

It is an interesting fact, that the shells of the fossil Lingula abound in the *phosphate of lime*, an essential element of bone. Their comparative deficiency in the carbonate of lime may perhaps account for their frequency in pure sandstones and other non-calcareous strata. The presence in the earliest Palæozoic deposits of creatures thus constituted to furnish appropriate food to the races endowed with bony skeletons, leads naturally to the inquiry whether fishes or some forms of vertebrate life may not have existed to prey upon them; nevertheless, we are scarcely warranted in placing so mere an inference in the scales of evidence where we have on the opposite side the universally-admitted absence of the equally indestructible bones and ganoid scales of the fishes of the earlier age.

Associated with the *Lingula* is a species of Obolus, a discoid Brachiopodous shell, equally characteristic of the oldest Palæozoic strata of Europe. It has been met with in Wisconsin (see Owen's Report); and I have myself found a few obscure specimens in the Primal slate of Pennsylvania.

Perhaps the most interesting organic remains of the Primal strata are their Trilobites; of these crustaceans, eight or nine species are already known to characterise the formation, though hitherto not a relic of the kind has been discovered in either of the Primal rocks of Pennsylvania. Of the known species, seven occur in the Primal sandstones of Wisconsin and Minnesota; they are described and admirably illustrated by Dr David Dale Owen, in the Report of his Geological Survey of Wisconsin, Iowa, and Minnesota. They are named *Dikelocephalus Minnesotensis*, *D. Miniskaensis*, *D. Iowensis*, *D. Granulosus*, *D. Pepinensis*, *Lonchocephalus Chippewaensis*, *Crepicephalus Wisconsensis;* these species bear a marked general likeness to the genus Paradoxides of Brongniart. Until this discovery by Dr Owen, no trilobite remains were known in any American formation older than the Auroral limestone. More recently a small specimen of apparently a new species of Calymene has been found in the Potsdam sandstone of the W. side of Lake Champlain, near Keesport, New York; the only instance in which a trilobite has yet been detected in this formation within the Appalachian chain.

About two years ago some very distinct impressions of an unusually large trilobite were discovered in Eastern Massachusetts, S. of Boston, upon altered argillaceous sandstone, in a geological zone previously regarded as entirely destitute of organic remains; they were submitted to Prof. Wm. B. Rogers, who recognised their trilobite structure, and after farther search for better specimens, ascertained their specific affinities. He has shown that they belong to the genus Paradoxides, and very probably to the also European species *Paradoxides spinosus*, a genus and species characteristic of the oldest fossiliferous formations of

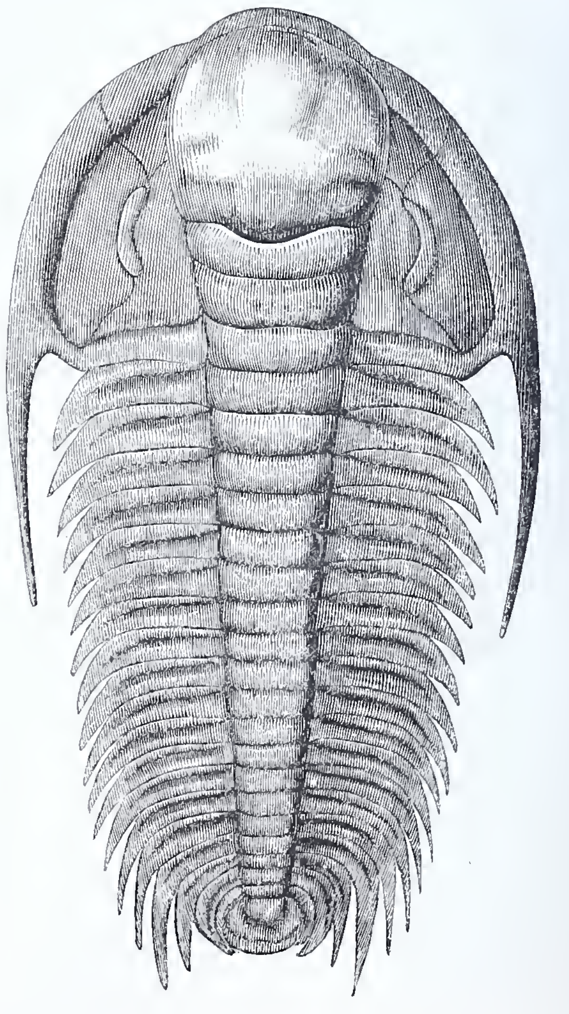


FIG. 590.—Paradoxides spinosus, from a quarry in Quincy, Massachusetts, one-third its natural size.

Europe.* These relics render it highly probable that some of the altered rocks of Eastern Massachusetts are coeval with the Primal series of the Appalachian basin.

An interesting analogy presents itself in the general structure of all these Primal or Primordial trilobites; it is their resemblance to the immature forms, or earlier stages of metamorphism, of the more complexly organised trilobites of later geological ages: evidence of this likeness will appear upon comparing *Paradoxides dikelocephalus*, or, in truth, any of these earlier crustaceans, with the figures upon Barrande's plate, exhibiting the transitions through which his species, *Sao hirsuta*, has passed from its lowest stages of development to full maturity. But a true homology of parts must be established to lend this resemblance any value.

ORGANIC REMAINS OF THE AURORAL STRATA.

None of the organic remains of the Primal strata recur in the Auroral or next overlying series. The total number of fossil species from the Appalachian Auroral rocks at this time recognised, cannot be less than one hundred, and all of them appear to have come into existence after the revolution in the physical geography of the Palæozoic waters, which closed the Primal formations, and initiated the very dissimilar Auroral ones. Marine plants, zoophytes, molluscs, and crustaceans, comprise the great organic types hitherto discovered in the Auroral limestones, the humblest forms being a few so-called fucoids or sea-weeds, and the highest, certain species of trilobites.

Of the Plants, the only species seen in Pennsylvania has been the *Palæophicus tubularis* of Hall (see *Palæontology of New York*, Vol. I. Plate II.), and even it is rare.

Of the Polyzoans, the *Retepora incepta* (*Palæontology of New York*, Plate IV.) may be frequently met with in the blue Auroral limestone of the anticlinal valley of Centre, Blair, and Bedford counties.

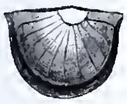


Fig. 591.—Leptæna incrassata.

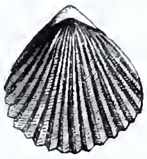


Fig. 592.—Atrypa plicifera.

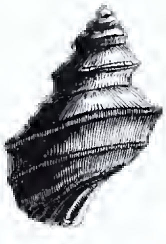


Fig. 593.—Murchisonia bicincta.

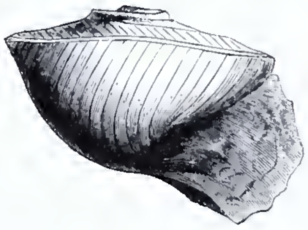


Fig. 594.—Raphistoma staminea.

The mollusca proper are much more numerous, nearly all the species figured and described in the *Palæontology of New York* being met with, though for the most part difficult of development, from the partially metamorphic limestone imbedding them.

A somewhat common species is the *Leptæna incrassata* (see Fig. 591), seen in Kishicoquillas and Nittany valleys. Another abundant brachiopodous shell occurring in the same lines of outcrop is the *Atrypa plicifera* (see Fig. 592).

Among the gasteropodous molluscs the *Pleurotomaria umbilicata*, *P. nucleolata* (see *Palæontology of New York*, Vol. I. Plate X.), *Ophileta levata*, *Murchisonia bicincta* (see Fig. 593), *Raphistoma striata*, *R. staminea* (Fig. 594), and the beautiful fossil *Maclurea magna* of Leseuer (Fig. 595), are perhaps the most common.

In the lower or sandy beds I have found *Euomphilus ungulatus*, *Maclurea matutinas*, and *Pleurotomaria turgida*, but this member of the formation is seldom well enough exposed in Pennsylvania to yield good fossils. The *Orthocerata* are not common; perhaps the species most frequently met with is *Orthoceras multicameratum*, a figure of which is here given (see Fig. 596). *Ormoceras tenuifilum* occurs, but more seldom. The commonest crustacean in this formation, in Pennsylvania, is the *Isotelus canalis* of Conrad. There also occurs a species of *Leperditia* (Cytherina), the *Leperditia ovata* of Rupert Jones—(see Fig. 697, p. 834).

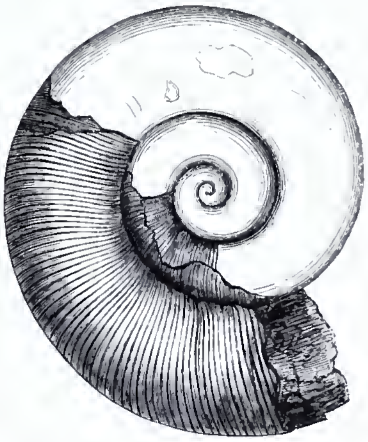


Fig. 595.—Maclurea magna.

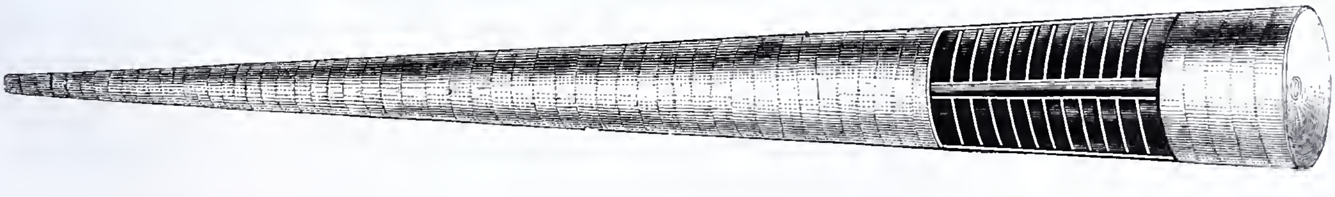


Fig. 596.—Orthoceras multicameratum.

---

* See "Proofs of the Protozoic Age of some of the Altered Rocks of Eastern Massachusetts," by Professor W. B. Rogers (*Proceedings of the American Academy of Arts and Sciences*, vol. iii.)

ORGANIC REMAINS OF THE MATINAL STRATA.

Matinal (*Trenton*) *Limestone.*—The entire Matinal series has up to this date afforded naturalists not fewer than 300 fossil species, and at least 200 of these are restricted to the Matinal limestone. It is a striking fact, that though this limestone stratum succeeds immediately other limestones, and without any physical break between them, its organic remains are almost entirely different—less, probably, than ten per cent being common to the two formations. So abrupt a transition in the inhabitants of the early Palæozoic waters is perhaps in part explained by the argillaceous nature of the Matinal rock, the muddy sediment unfitting the waters for the species of the magnesian limestone sea, and adapting them to new races in more express adjustment with them. It is worthy of remark, that some of these species, confined to the Trenton rock, New York, pass down into the Auroral limestone in Pennsylvania and Virginia.

In Pennsylvania the Matinal limestone is not always present in the series, and in none of its discovered localities is it as favourably exposed for the detection of its organic remains as in the districts lying N. and W., for it is never horizontal, nor free from more or less of metamorphism; still it presents a good variety of its well-known fossils. Those more commonly met with, or by which the formation may be most readily recognised, are here referred to and figured.

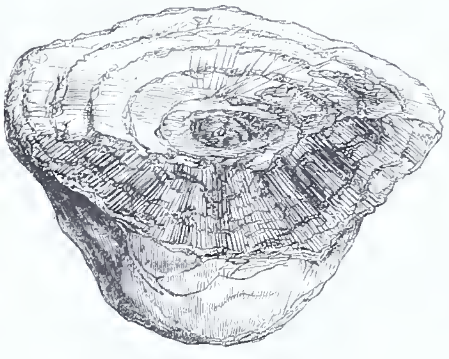


FIG. 597.—Chætetes lycoperdon.

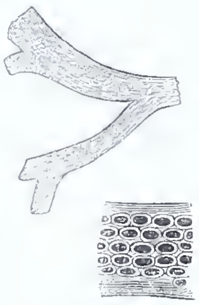


FIG. 598.—Strictopora acuta.

The PLANTS of the formation consist in our State, as elsewhere, of those obscure forms called *sea-weeds;* one of the commonest I am disposed to identify with the *Buthotrephis gracilis* of Hall.

Of the CORALS, perhaps the most abundant is the *Chætetes lycoperdon*, especially the spherical form of it, shown in the annexed figure, which represents one margin broken, disclosing the slender radiating tubes.

Another frequent zoophyte is the *Strictopora acuta*, here shown (Fig. 598), with a portion of one branch magnified to show its oval cells. This supposed coral resembles much in structure the genus *Eschapora*, which naturalists no longer regard as belonging to the zoophytes, but to the class *Polyzoa* (or *Bryozoa*) of the Mollusca: there can be little doubt, indeed, that such is its true place in the animal kingdom.

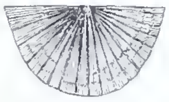


FIG. 599.—Leptæna sericea.

Among the fossil SHELLS of the formation, one of the most common is the beautiful little semicircular brachiopod *Leptæna sericea* (Fig. 599). This small species is recognised by its fine radiating striæ, grouped between occasional more prominent ones, and by its fine granulated surface. Another very common brachiopod, of the same genus, is the *Leptæna alternata* (Fig. 600), a large half-oval shell, with a minutely-perforated beak, the dorsal valve here shown being very convex, especially towards the margin, but flatter towards the hinge: its surface exhibits delicate rounded radiating striæ or threads, unequally alternating with coarser ones.

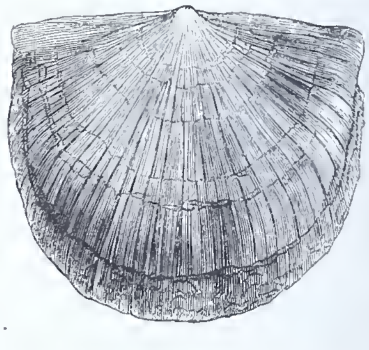


FIG. 600.—Leptæna alternata.

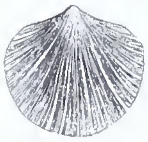


FIG. 601.—Orthis testudinaria.

Another brachiopodous genus, *Orthis*, is represented in this rock by *Orthis testudinaria* and *Orthis pectenella*, both very abundant fossils in Pennsylvania—(Figs. 601, 602). The *Orthis testudinaria*, named for its fancied resemblance to a turtle, is interesting as being also a characterestic species of the lower Palæozoic rocks of Europe, and therefore one of the links serving to link together the formations of the two sides of the Atlantic.

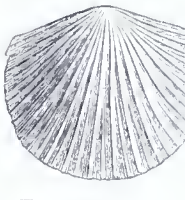


FIG. 602.—Orthis pectenella. (N. S.?)

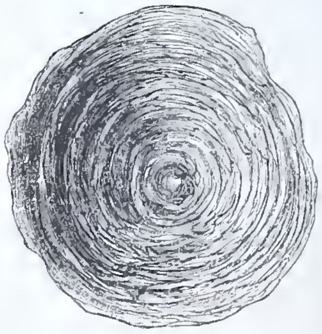


FIG. 603.—Orbicula. (N. S.?)

The other species, *Orthis pectenella*, if not likewise a European form, resembles one, the *O. calligramma*, very closely. Another brachiopod, not so frequently met with as the preceding, is an *Orbicula* or *Crania* (Fig. 603), a large discoid shell, with a small elevated conical apex, somewhat centrally placed, and a surface rough with rather irregular concentric scaly ridges. It differs from any already-described older Palæozoic *Orbiculæ* in the sub-central position of the apex, and is probably a new species.

A very beautiful small brachiopod, the *Lingula curta* (Fig. 604), is also somewhat common; and in the Valley of Virginia, where the Matinal limestone abounds in black slate, it is very abundant. This fossil is one of the few which occur also in the Matinal black slate. It is to be met with in both formations in the Kittatinny Valley, and in Centre and Bedford counties.

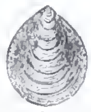


FIG. 604.—Lingula curta.

Of the lamellibranchiate shells, or bivalves, one of the most common is the *Ambonychia bellastriata* (Fig. 605), a beautiful fossil, with a long slightly-curved beak, very oblique to the short cardinal line. Its surface shows fine radiating striæ, intersected by concentric lines, marking successive growth. The ambones are very protuberant.

In the Gasteropods this formation, in Pennsylvania, most abounds perhaps in species of the widely-ranging genus Pleurotomaria. One of the best-defined is the *Pleurotomaria subconica*, here presented (Fig. 606). This neatly-shaped univalve, often mistaken for a *Trochus*, has an elevated conical spire about five volutions, and a slightly-projecting carina or ridge above the suture or groove. The aperture is squarish, and the surface marked with fine bending striæ. Our figure is derived from a cast.

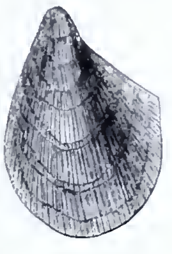


Fig. 605.—Ambonychia bellastriata.

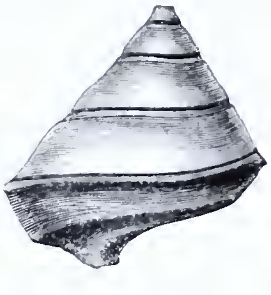


Fig. 606.—Pleurotomaria subconica.

Another beautiful and common fossil of the formation is the *Bellerophon bilobatus* (Fig. 607), found also in the overlying Matinal shales. This fossil is not distinctive of the Matinal period, for it occurs likewise in Surgent strata; and, as is usually the case with long-enduring species, it has a commensurately wide geographical distribution, being one of the best-known shells of the Cambrian (Lower Silurian) rocks of Great Britain.

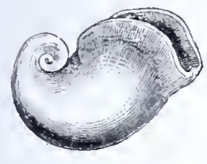


Fig. 607.—Bellerophon bilobatus.

The nature and affinities of the animal in the shell called Bellerophon are rather doubtful, some naturalists regarding it as a Gasteropod; others viewing it to be a Cephalopod destitute of the usual partitions; and others, again, believing it to be a Heteropod, allied to the creature called *Carinaria*, one of the floating glass-shells.

Among the Orthocerata of the Matinal limestone, one of the most frequently encountered is the curiously-ringed *Orthoceras vertebrale* (Fig. 608). This appears to have been a rather fragile shell, for I have never seen it entire.

A curious fossil, sometimes referred to the Cephalopodous mollusca, but believed by many naturalists to rank with the Pteropods, is the Conularia, one species of which, *Conularia Trentonensis*, is not infrequent in the Matinal limestone of Pennsylvania, but the specimens are seldom perfect. The annexed figure is therefore copied from an excellent representation (Fig. 609) given by Professor Hall in his *Palæontology of New York*, Plate LIX., fig. 4.

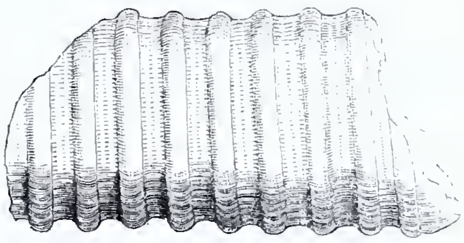


Fig. 608.—Orthoceras vertebrale.

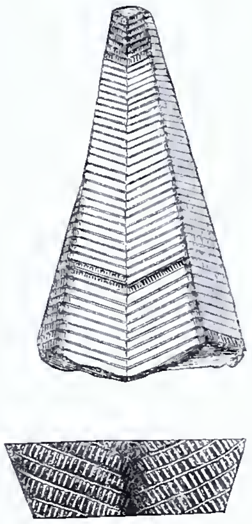


Fig. 609.—Conularia Trentonensis.

But by far the most attractive organic remains of the formation are its *Trilobites.* Of these there are nearly twenty species known, more than one half of which are restricted to the Matinal limestone, the remainder ascending into the Matinal shale. One of the most frequently found is the *Isotelus gigas*, Dekay, or *Asaphus platycephalus*, Stokes, of which a figure is here presented (Fig. 610). This fossil, occasionally found also in the Matinal shale, is eminently distinctive of the Matinal formations, and is equally restricted in Europe to the rocks of corresponding age—the Upper Cambrian or Lower Silurian. According to Barrande, the foremost authority on the subject of Trilobites, the American genus *Isotelus* has not the value of a distinct genus, but is subordinate to the great genus *Asaphus*—*Isotelus gigas* being identical with *Asaphus platycephalus*. This interesting crustacean is sometimes of enormous size, fragments having been found in the Matinal shales of Ohio, which indicate that the perfect animal must in some instances have been nearly 2 feet long—exemplifying the general law, that the size of a race is usually greatest in that formation in which it seems to culminate, either in the variety of its species or in the multitude of its individuals. In Pennsylvania I have occasionally, though rarely, met with this fossil in the Matinal shales. Its greater abundance and size in Ohio are obviously, as Professor Hall suggests, connected with the very calcareous nature of the same formation in that region; possibly it is likewise due to the greater remoteness of the western locality from the shore of the ancient Matinal waters, and therefore to more perfectly marine conditions.

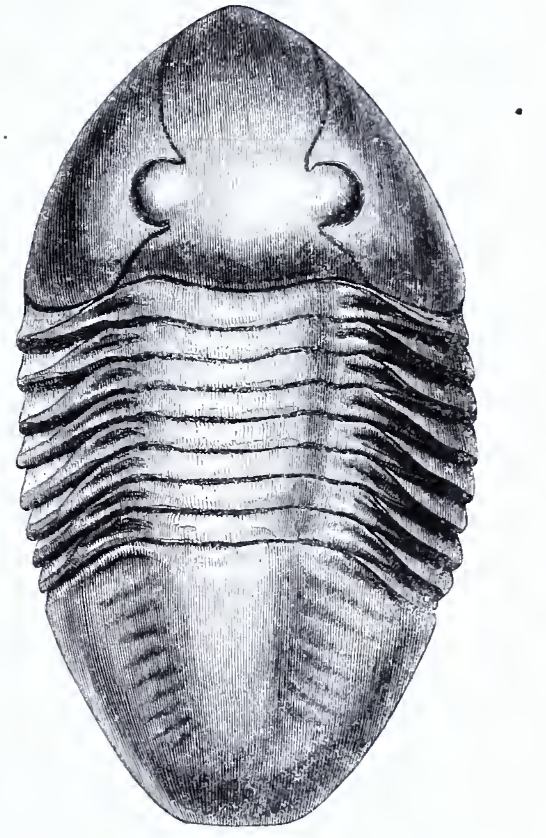


Fig. 610.—Isotelus gigas.

Another interesting trilobite common in the Matinal limestone is the *Trinucleus concentricus* (Fig. 611). This, like the *Isotelus*, characterises both divisions of the Matinal series, but is found nowhere else in the Palæozoic column; and it is, equally with that fossil, distinctive of the Upper Cambrian or Lower Silurian deposits of

England. This beautiful and easily-recognised fossil is of common occurrence in the Matinal limestone of the anticlinal valleys of Central Pennsylvania. It occurs with *Isotelus gigas*, *Calymene senaria*, *Beyrichia lobatus*, and *Leperditia ovata*, abundantly in the neighbourhood of Pine Grove, Aaronsburg, and Potter's Fort, in Penn's Valley, and also in Nittany and Nippenose valleys, and in Milligan's Cove. This trilobite may be recognised at first sight by the semicircular shape of its buckler, which, when perfect, is prolonged into a slender spine at each side. At each end the marginal band is pitted with three, four, or five rows of deep round punctures, very like those upon a thimble. An opinion prevails among naturalists that the animals of the genus Trinucleus were, in their mature state, destitute of eyes, though some of the species appear to have possessed them while in the younger stages of their growth.

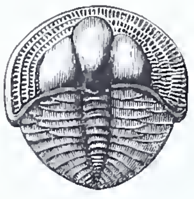


Fig. 611.—Trinucleus concentricus.

As no higher organisms have been discovered in the much-ransacked strata of this Matinal period, the crustaceans here described must be viewed as the dominant races of the animal world of that day.

ORGANIC REMAINS OF THE MATINAL SHALE.

The upper member of the Matinal series, the Matinal shale (Hudson River group of New York), is characterised by the organic remains of the same classes of animals as are entombed in the lower member, or Matinal limestone. Viewing the black slate which intervenes between the limestone and the shale as a member of the latter, there are about seventy known species in this upper Matinal formation, more than twenty of which are common to it and the underlying Matinal limestone. The two divisions of the series are furthermore linked by a still larger proportion of common genera. The Matinal shale, moreover, contains no fossil remains belonging to races higher in the scale of organisation than the highest seen in the limestone under it. Trilobites are still the most advanced forms of extinct animal life.

A prevailing state of metamorphism, amounting often to a more or less developed cleavage, and always to a tendency to transverse fracture, obstructs greatly the recognition of the smaller and more obscure fossils; and an extensive infiltration of the surface-waters, consequent upon it, has dissolved out nearly all the organic remains, leaving mere casts of their surfaces. The number, therefore, of well-identified species is much less than in those tracts of New York and the Western States where the strata repose in their original horizontal position, and have escaped metamorphic and crushing action. But notwithstanding these drawbacks, I am able to exhibit figures here of an ample number of characteristic forms. Beginning with those which occur most abundantly in the Matinal black slate, we have first the *Graptolithus pristis* (Fig. 612). These delicate fossils, some of which resemble a minute quill, have a straight central stem, margined by a compressed membrane, notched with small acute teeth like a little saw. The true nature of the graptolite remains a matter of some uncertainty. It is believed that its nearest known modern representative is the genus Virgularia.

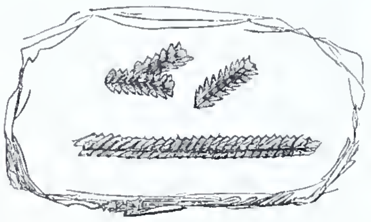


Fig. 612.—Graptolithus pristis.

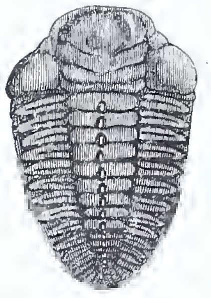


Fig. 613.—Calymene Beckii.

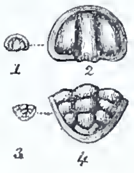


Fig. 614.—Agnostos lobatus. (1 and 3 natural size, 2 and 4 enlarged.)

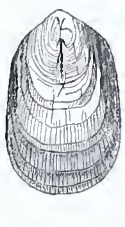


Fig. 615.—Lingula quadrata.

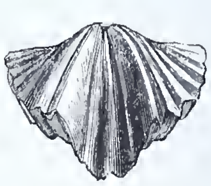


Fig. 616.—Delthyris lynx.

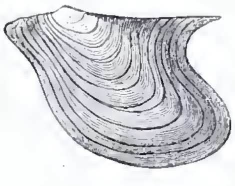


Fig. 617.—Avicula insueta.

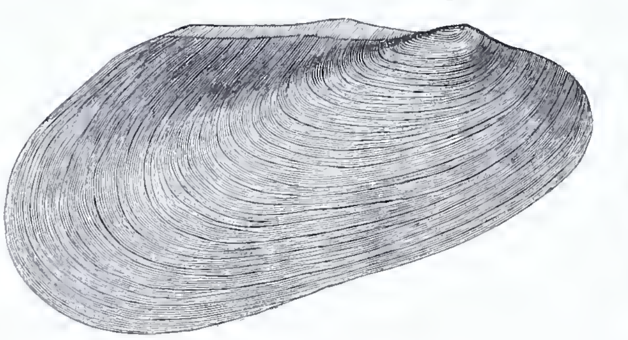


Fig. 618.—Modiolopsis modiolaris.

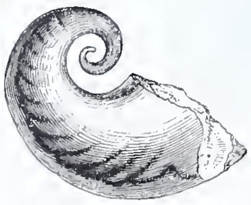


Fig. 619.—Cyrtolites ornatus.

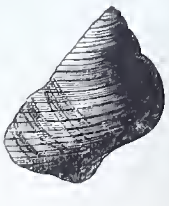


Fig. 620.—Pleurotomaria bilix.

Another common fossil of the black slate is the *Lingula curta*, already mentioned as of frequent occurrence in the Matinal limestone, to which rock, indeed, the black slate is nearly as subordinate as it is to the Matinal shale. Associated with these, we not unfrequently find the delicate trilobite, *Calymene Beckii*, (Fig. 613). They are met with together in Penn's Valley and in Milligan's Cove. This fossil is not often found entire; it seems to have been too slightly articulated to retain its form after death; the buckler or head-piece is its most easily recognised portion. There is another little crustacean, *Beyrichia* (*Agnostos*) *lobatus* (Fig. 614), sometimes seen in the Matinal shale. The shells of this great argillaceous formation belong to all the great classes of Mollusca. The brachiopods are represented by *Lingula quadrata* (Fig. 615), an unusually large robust species, with an approximately square outline, whence its name. Another brachiopod is *Delthyris (spirifer) lynx*, (Fig. 616). To these may be added several of the brachiopods of the Matinal limestone, *Leptæna sericea*, *L. alternata*, and *Orthis pectenella*, &c.

Among the Conchifers, or common bivalve shells, best preserved or oftenest seen, are the *Avicula insueta* (Fig. 617), and *Modiolopsis modiolaris* (Fig. 618). *Cyrtolites ornatus* (Fig. 619), probably the shell of a pteropod, is a very common fossil of the Matinal shale, and in Pennsylvania is restricted to it. Our figure is copied from Plate LXXXIV. of Hall's *Palæontology of New York* (which see).

Another univalve, likewise confined to it, is the *Pleurotomaria bilix* (Fig. 620). This beautiful little shell, which has hardly the character of a true Pleurotomaria, occurs occasionally in the Matinal shale in the limestone valleys of Centre County. It is much more common in the Western States.

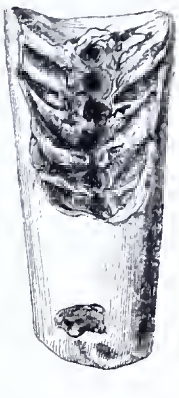


Fig. 621.—Ormoceras crebriseptum.

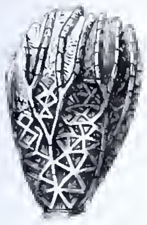


Fig. 622.—Glyptocrinus decadactylus.

The Matinal Orthocerata are occasionally seen in Pennsylvania. The annexed cut (Fig. 621) represents a fragment of one of them, *Ormoceras crebriseptum*, displaying the internal structure, but not very clearly.

The middle and upper beds of the Matinal shale contain layers abounding in the joints of unknown species of Crinoidea. Possibly some of them belong to the beautiful fossil *Glyptocrinus decadactylus* (Fig. 622), abundant in the corresponding formation in Ohio and Kentucky. The annexed figure is from Cincinnati.

The prevailing fossils of the Matinal shale in the great limestone valleys of the mountain-chain of the State are—

Heterocrinus, *Ambonychia radiata*, *Avicula insueta*, *Modiolopsis modiolaris*, *Pleurotomaria bilix*, *Murchisonia gracilis*, *Cyrtolites ornatus*, *Lingula quadrata*, *Lingula curta*, *Leptæna sericea*, *L. alternata*, *Orthis testudinaria*, *Atrypa increbescens*, *Spirifer lynx*, *Ormoceras crebriseptum*, *Endoceras proteiforme*, *Leperditia fabulites*, *Trinucleus concentricus*, *Isotelus gigas*, &c.

ORGANIC REMAINS OF THE LEVANT STRATA.

The formations which immediately succeed the Matinal deposits are singularly destitute of fossils, not one species of the nearly 300 met with below reappearing in this group. It would seem, indeed, that the changes in the earth's surface which terminated the Older, and ushered in the Middle Palæozoic sediments, swept out of existence all previously-created races, without yet adapting the region for the reception of new forms of animal life to replace them.

These did not come upon the scene in any number until the next succeeding or Surgent period, nor even then in the profusion of their predecessors of the Auroral and Matinal ages. The transition at which we have now arrived—that from the Matinal shale to the Levant sandstone—is by far the widest break we know in the chain of Palæozoic life. It amounts, as I have elsewhere shown, to an almost total extinction of all the earlier species, and the substitution at successive epochs of wholly new ones. In Pennsylvania and Virginia this break is even more complete than it is in New York; for, in the latter State, relics of three or four species characteristic of the Matinal rocks, or about one per cent, have been met with in the Surgent and Scalent strata, whereas in Pennsylvania not a single species has been found on both sides of this great gulf. This important fact, and the commensurate one of a widely-extended physical break between the Matinal and the later formations, amounting in many quarters to positive unconformity, and throughout the Western States to a wide gap or hiatus in the succession of formations, have influenced me to classify the three lower groups apart from the middle formations upon which we are now entering.

The principal organic relic seen in the Levant strata of Pennsylvania is the curious fossil, *Arthrophycus Harlani*, here represented (Fig. 623). It is supposed to be a marine plant, and for a long time bore the name of *Fucoides Harlani.* Our figure represents only the upper branching extremity, the whole plant consisting of a rounded and apparently articulated or transversely-grooved flexible stem, with simple subdivisions of nearly the same thickness throughout. The long flexible stems are often seen penetrating the upper layers of the Levant white sandstone perpendicularly through a length of from one to two feet, and spreading on the upper surfaces of the beds in large curled bunches resembling closely-matted tufts of hair. Their usual position suggests the notion of sea-weeds floating perpendicularly just above the bed of the ocean, and, while in this position, quietly imbedded by sand silted in among them.

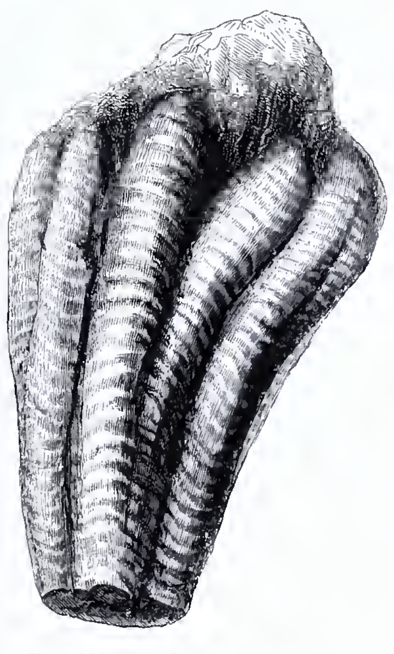


Fig. 623.—Arthrophycus Harlani.

Hitherto this curious fossil has been found only in the Upper Levant sandstone, the equivalent of the Medina sandstone of New York. It is particularly abundant in some of the outcrops of this formation which cross the

Juniata River, especially in Mifflin County. A very much reticulated variety occurs plentifully in the "Long Narrows," below Lewistown, upon the uppermost beds of the sandstone, just under the base of the Surgent slates. In none of the specimens do we see any traces of the vegetable tissue, but only a cast of the general surface of the plant in the sandstone.

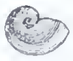


FIG. 624.—Bucania trilobatus.

In some of the layers of the same upper sandstone we occasionally, though rarely, discern two or three small shells. One of these is a little spiral fossil, *Bucania trilobatus*, Hall, a cast of which is here figured (Fig. 624). It resembles somewhat a bellerophon. Another small fossil is *Lingula cuneata*, a wedge-shaped lingula, sharply pointed at the beak, whence its specific name. I have only seen it in the highest layers of the Levant sandstone. These are the only organic remains of the formation which I have noticed in Pennsylvania.

ORGANIC REMAINS OF THE SURGENT STRATA.

This very complex formation, composed of fissile slates, calcareous shales or marls, non-calcareous shales, and firmly-cemented ferruginous sandstones, contains a proportionate variety of organic remains. The total list of its species, as described in the *Palæontology of New York*, amounted, in 1852, to more than 100, and we may set down the number now known at not less than 120, or more than six times the whole number hitherto procured from the Levant rocks in all their localities. It is the first or lowest platform upon which we find the true Silurian (Upper Silurian) types of Europe, in the American Palæozoic strata. Only four or five of its fossils belong likewise to the Matinal formations below the great horizon of interruption above spoken of. These are *Bellerophon trilobatus*, *Delthyris lynx*, *Leptæna alternata*, *Leptæna depressa*, and *Calymene Blumenbachii;* but the validity of the evidence as to some, at least, of these being genuine Surgent fossils, is rather doubtful. Some fifteen or sixteen of its species this formation shares in common with the group of strata—the Surgent series—which next succeeds it, proving what the physical evidence also shows, that these two Middle Palæozoic formations are somewhat intimately blended.

Plants, or at least plant-like impressions, rather abound in the laminated argillaceous rocks or slates of the lower and middle members of the Surgent series, but the number of well-defined species in Pennsylvania is apparently small. By far the most common type is that named *Buthotrephis gracilis* by Hall. A specimen of what is perhaps another and new species of Buthotrephis, from Montour's Ridge, is here figured (Fig. 625). Another plant-like fossil, less frequently found, is represented in the annexed cut (Fig. 626); it is always two-lobed, and is the *Fucoides bilobatus* of Vanuxem, or the *Rusophycus bilobatus* of Hall. It is crossed by strong wrinkles, and some specimens display a distinct stem proceeding from the groove which divides the two lobes. The two-lobed mass is probably the impression of the root of a plant, the stem of which was too easily disorganised to leave an equally distinct trace of its form.

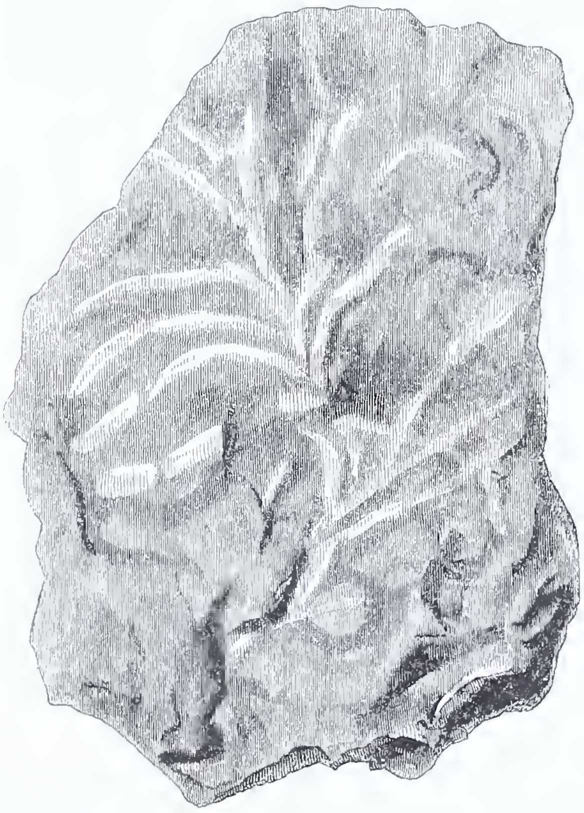


FIG. 625.—Buthotrephis gracilis (?)

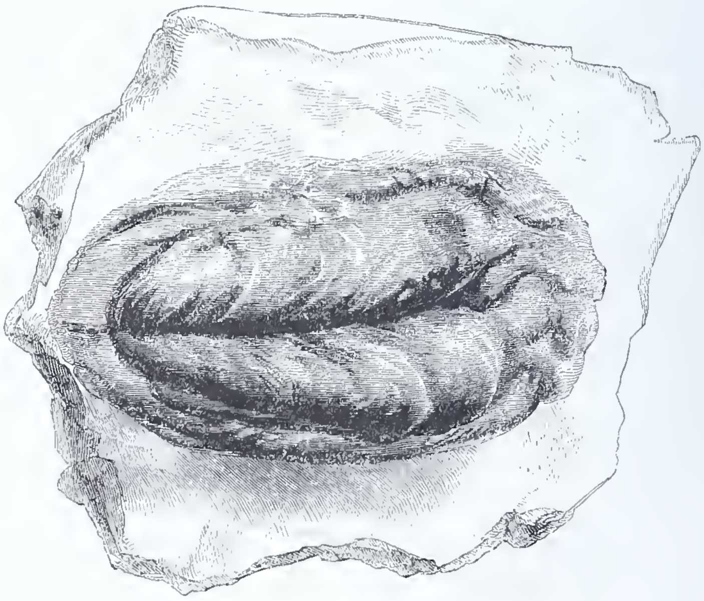


FIG. 626.—Rusophycus bilobatus.

Of the animal remains imbedded in the Surgent strata, we occasionally come upon a puzzling form, the *Cornulites*, a slender cone-shaped fossil, composed of successive rings transversely striated on their outer surface. The true place of this fossil in the animal kingdom is not at present known; there are probably several species,—one of these is the *Cornulites flexuosis*. Our own specimen (Fig. 627), found in the Surgent ore sandstone, above the fossiliferous iron-ore in Blair County, belongs apparently to another species; but until more is known of their structure, I refrain from giving it a specific name.

The Surgent series, or Clinton group, contains several interesting species of conchifera or bivalve shells belonging to the genera Avicula, Modiolopsis, Tellinomya, and Orthonota, &c. One of the most common and pleasing of these is the *Avicula subplana*, found in the shales of the fossiliferous iron-ore, and sometimes in the ore itself (see Fig. 628). In the *Palæontology of New York* this shell is figured as characterising the Niagara group; several similar instances are known of New York Niagara fossils occurring in the Surgent (Clinton) rocks of Pennsylvania.

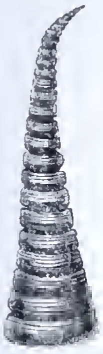


Fig. 627.—Cornulites.

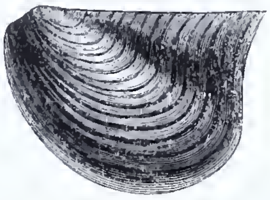


Fig. 628.—Avicula subplana.

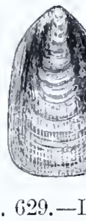


Fig. 629.—Lingula oblonga.

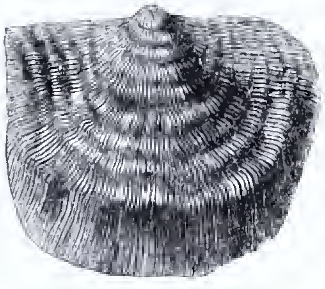


Fig. 630.—Leptæna depressa.

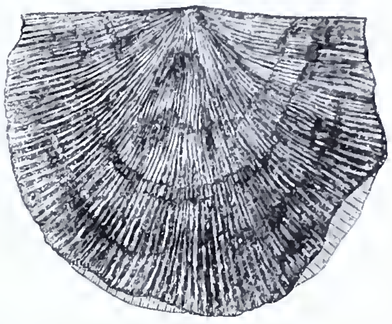


Fig. 631.—Leptæna patenta.

This formation abounds in shells of the brachiopodous type, containing several species of Lingula, Leptæna, Orthis, Spirifer, Atrypa, etc.; one of the most common is the *Lingula oblonga*, here shown (see Fig. 629), recognised by its nearly parallel straight sides, pointed and convex beak, and obtusely-rounded corners at the base. It occurs in the slates adjoining the iron sandstone, and also in the fossiliferous ore.

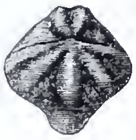


Fig. 632.—Atrypa congesta.

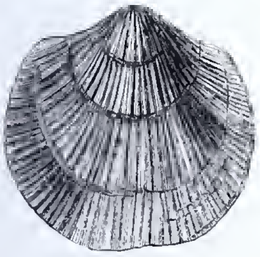


Fig. 633.—Atrypa reticularis.

A very distinctive fossil of the formation in Pennsylvania is the beautifully-corrugated shell, *Leptæna depressa* (Fig. 630), found in New York in all the strata from this formation to the Upper Helderberg or Post-meridian limestone; it may sometimes be seen in the slate adhering to the fossiliferous iron-ore. Another shell of the same genus, frequent in the same part of the formation, is the *Leptæna patenta* (Fig. 631); its surface is marked by strong unequal striæ crossed by fine concentric lines of growth.

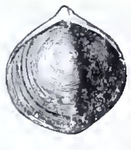


Fig. 634.—Atrypa intermedia.

Of the abundant genus Atrypa, the Surgent rocks contain nearly twenty species; among the most easily recognised of these are the *Atrypa congesta* (Fig. 632), distinguished by a deep central furrow extending from the beak to the base of the dorsal valve; *Atrypa reticularis*, a more variable species, distributed from the Surgent to the Cadent strata (Fig. 633), and *Atrypa intermedia* (Fig. 634), a wide shell compressed at the base, and having its two valves of nearly equal convexity.

Fig. 635.—Orthus elegantula.

The *Atrypa reticularis*, like most fossils of a wide range in time, has a correspondingly broad distribution geographically. It is the *Atrypa affinis* of Sowerby, and occurs abundantly in the Upper Silurian rocks of Great Britain.

Orthis elegantula (Fig. 635) is another brachiopod of this formation.

The Cephalopoda of this formation are not abundant. One of the most common is the *Orthoceras imbricatum* (Fig. 636), a species which in New York occurs in the Scalent or Niagara group (see *Palæontology of New York*, Vol. II., Plate 62).

The most common crustaceans of the Surgent strata of Pennsylvania are the *Calymene* (*Hemicrypturus*) *Clintoni*, *Beyrichia lata*, and *Leperditia Pennsylvanica*.

Calymene Clintoni (Fig. 637) is frequently met with entire or in fragments within or near the fossiliferous iron-ore, and on the iron sandstone. I have seen it in both positions in Montour's Ridge; *Phacops limulurus* sometimes occurs along with it, and so also *Calymene Blumenbachii*, though both of these tribolites are more characteristic of the Scalent or Niagara formation.

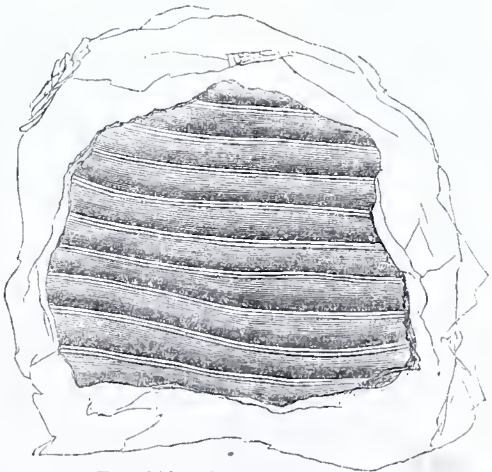


Fig. 636.—Orthoceras imbricatum.

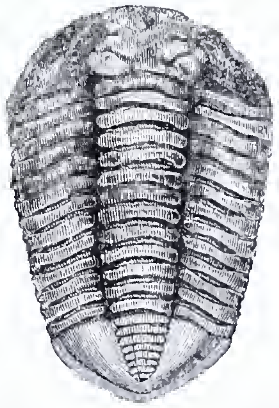


Fig. 637.—Calymene Clintoni.

The *Leperditia Pennsylvanica*, Jones, is a crustacean of a different group, belonging to a bivalve Entomostraea—(Fig. 699, p. 834.) This beautiful *Leperditia*

(*Cytherina*), identified as a new species by T. Rupert Jones, Esq., Curator to the Geological Society of London, is deemed by him to be very near *L. Balthica* of Europe, and *L. Arctica* of North America; it has a very distinct eye-spot. The specimen figured is from a greyish limestone of the Surgent variegated marls near Barre Forge.

The limestone bands of the middle and upper portions of the Surgent series contain two or three species of the minute seed-like fossil formerly called *Agnostus*, and now *Beyrichia*; two of these, *Beyrichia Maccoyiana*, Jones (Fig. 695, p. 834), and *Beyrichia Pennsylvanica*, Jones, identified for me by Mr Jones, are figured on page 834; their natural size is about one-fourth of that represented.

ORGANIC REMAINS OF THE SCALENT STRATA.

The Scalent series of Pennsylvania, on the horizon of the Onondaga salt group and water-lime stratum of New York, contains, except in the latter or Scalent limestone, extremely few organic remains; the Scalent variegated marls, none beyond a few Beyrichiæ and Leperditiæ; and the Scalent grey marls only the same, with scarcely greater frequency. In some of its N.W. outcrops in the Appalachian chain, the Scalent limestone presents numerous specimens of *Beyrichia Maccoyiana*, Jones.

Beyrichia Pennsylvanica, Jones, together with the *Leperditia alta*, Conrad, and the *Tentaculites ornatus*, Vanuxem (Fig. 638), identify this rock as its stratigraphical position does with the water-lime of New York. The Niagara limestone of New York and the Western States does not extend into Pennsylvania, being confined apparently to the N. side of the great Appalachian basin. That interesting formation has furnished the palæontologist of New York with more than two hundred and twenty species of fossils, a small number of which,—less than twenty,—it shares in common with the Surgent or Clinton series—the Surgent of Pennsylvania containing, as already intimated, a somewhat larger proportion of them. The trilobites of the Niagara formation belong to the genera Cybele, Acidaspis, Phaeops, Ceraurus, Calymene, Homalonotus, Bumastis, Lichas, Arges, and Proetus. *Phaeops limulurus*, *Calymene Blumenbachii*, and *Homalonotus delphinocephalus*, occur in the middle calcareous beds of the Surgent formation, both in Pennsylvania and Virginia; the *Phaeops* near Matilda Furnace on the Juniata, and near the hot springs; the *Calymene*, in the slates of the iron sandstone at Danville; and the *Homalonotus* in Blair County.

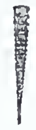


Fig. 638.—Tentaculites ornatus.

Reviewing the organic remains indicated in the previously-mentioned formations, none of them, it will be perceived, are higher in the scale of organic life than trilobites and cephalopodous molluscs. No remains of fishes, undoubtedly such, have been discovered in these strata, nor indeed in the rocks of equivalent age in Europe. For a while it was supposed that certain long slender bone-like fossils, found in the Niagara limestone and in the Wenlock formation of England, were genuine remains of fishes; and upon this view one of them has been figured and described in the *Palæontology of New York* under the name of *Onchus Deweii*, Hall (Fig. 639, copied from Plate LXXI., *Palæontology of New York*). These supposed relics of Silurian fishes have all of them, however, been pronounced, after a critical examination, to be merely portions of crustaceans. It must be enunciated then as a general fact, that hitherto no traces have been discovered of any vertebrate animal whatsoever having lived during all those earlier Palæozoic ages which are embraced in the Cambrian and Silurian periods of the English geologists, or the equivalent Primal, Auroral, Matinal, Levant, Surgent, and Scalent periods according to the nomenclature of the Pennsylvania Survey. The earliest date at which actual fishes appeared in the Appalachian or Palæozoic sea of North America was that of the Post-meridian strata, numerous specimens of the ganiod class having been recently found in the upper Cliff or Corniferous limestone of Ohio, locally called the Sandusky limestone. This rock is apparently very nearly on the horizon of the lowest Devonian strata of Europe, in which corresponding icthyic remains are well known.

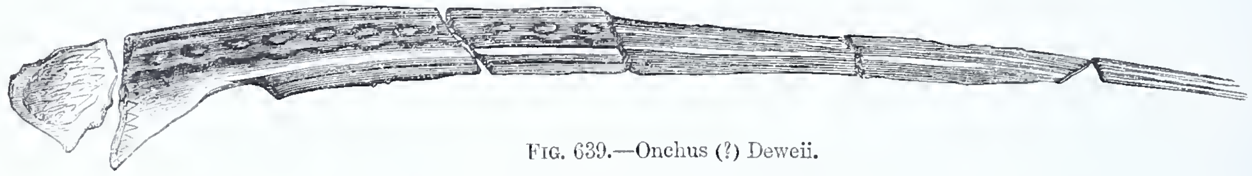


Fig. 639.—Onchus (?) Deweii.

ORGANIC REMAINS OF THE PRE-MERIDIAN STRATA.

The pre-Meridian series of Pennsylvania, like its equivalent formation, the Lower Helderberg limestone of New York, is in many localities replete in organic remains, though, being generally deficient in the very fossiliferous limestone shales which in New York accompany the limestone, its variety of species is commensurately smaller. The third volume of the *Palæontology of New York*, designed for the description of the fossil of this and the next later formations, not being yet in print, we have no means of learning the total number of species developed by the well-supported and skilfully-conducted palæontological exploration of that State; it is probable, however, that the species about to be brought to light will exceed two hundred. Anticipating the publication, long before this, of the *Palæontology of New York*, the accepted guide to the fossils of the eastern portion of the Appalachian basin, and controlled by the narrow limits of the means placed at my disposal, no attempt was made in the Geological Survey of Pennsylvania to collect any but the organic remains of the coal-formation, for description and delineation;

especially as I was conscious that their state of preservation from well-known geological conditions is far inferior, for all purposes of palæontological research, to the beautiful petrifactions in the less consolidated, more horizontal rocks of New York, the Western States, and Canada. The non-appearance of the long-looked-for fresh descriptions of the fossils of the middle and later Palæozoic formations, compels me to retain, for the species found in Pennsylvania, the names assigned them in the Geological Survey of New York before its special palæontological exploration was commenced, though I am aware that the researches there and elsewhere in progress may alter some of the generic titles, and even some of the specific ones.

The most abundant fossils of the Pre-meridian limestone of Pennsylvania are several beautiful brachiopodous shells. One of these is the *Atrypa peculiaris*, Conrad (see Fig. 640), assigned in the New York Survey to the Meridian or Oriskany sandstone. This species is easily known by the deep depression of the basal edge of the lower valve. The annexed figure represents another fossil common to the Pre-meridian limestone and the sandy shales which intervene between it and the Meridian sandstone (see Fig. 641). It appears to be a new species of Atrypa; but, under the circumstances explained, I do not deem it worth while to confer upon it a name likely soon to be superseded.

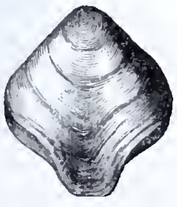


Fig. 640.—Atrypa peculiaris.

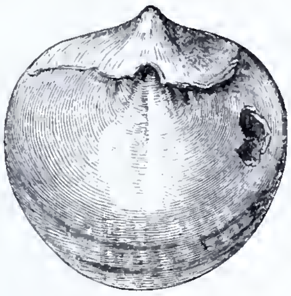


Fig. 641.—Atrypa.

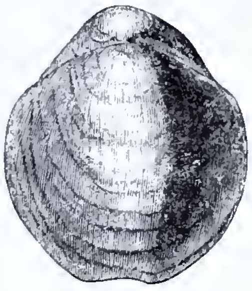


Fig. 642.—Atrypa lævis.

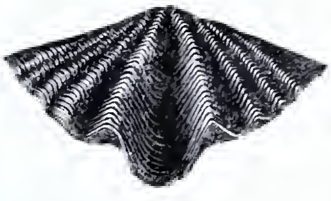


Fig. 643.—Delthyris macropleura.

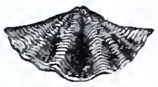


Fig. 644.—Spirifer sulcatis.

Another common fossil is the *Merista* (*Atrypa*) *lævis* (see Fig. 642). A still more abundant shell is *Delthyris* (*Spirifer*) *macropleura* (see Fig. 643); but this, like *Spirifer sulcatis* (see Fig. 644), occurs sometimes also in the Meridian sandstone. Another brachiopod more seldom found is the *Rhynconella nobilis*, Hall (see Fig. 645). In the absence of good printed figures for comparison, I am in some doubt whether this may not be Hall's *Rhynconella mutabulis*—(See *Descriptions of New Species of Palæozoic Fossils*, by James Hall). This shell resembles in many respects the European Silurian fossils, *Rhynconella Stricklandii*, Sowerby; but its profile is somewhat different, and the margins of the valves are much less serrated.

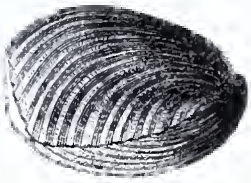


Fig. 645.—Rhynconella nobilis.

One of the most common and distinctive fossils of the formation is the *Pentamerus galeatus* (see Fig. 646), equally characteristic of the Wenlock limestone of England.

A Platyostoma, of which a figure is here annexed (see Fig. 647), is to be met with in some localities within this limestone; but it is rather more frequently found in the cherty layers which form a passage from the formation into the overlying Meridian sandstone. Lamellibranchiate or true bivalve shells are not common in the Pre-meridian limestone. Of brachiopods, *Strophomena* (*Leptæna*) *punctulifera*, Conrad (see Fig. 648) is a characteristic species. This fossil is often seen in the chert, but never, that I know, in the overlying Meridian sandstone.

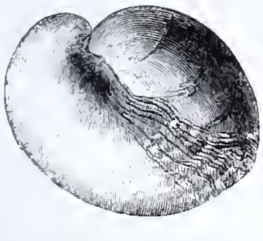


Fig. 646.—Pentamerus galeatus.

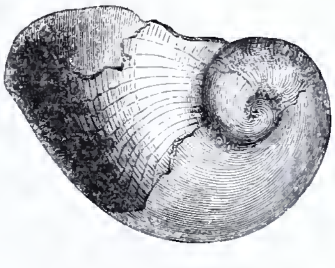


Fig. 647.—Platyostoma.

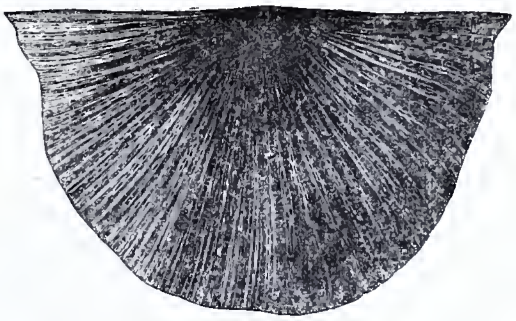


Fig. 648.—Strophomena punctulifera.

ORGANIC REMAINS OF THE MERIDIAN STRATA.

The sandy shales of this series underlying the coarse Meridian sandstone contain two or three fossils which I think are as yet undescribed species, a Calymene and an Orbicula especially. Palæontologists will find access to these fossiliferous layers near Moorestown, N. of Montour's Ridge, and also at Frankstown, on the Juniata.

The Meridian sandstone being arenaceous and porous, and also very generally much jointed, in Pennsylvania, presents its organic remains chiefly in the state of casts or moulds of their exterior surfaces, the fossils themselves having long since been dissolved away. As a consequence, the more fossiliferous beds are at their outcrops usually deeply pitted with the cavities once occupied by the fossils. These are the more conspicuous from the unusual size of nearly all the organic remains, all of which are nearly brachiopodous molluscs. I shall present here figures of the three species most usually met with. One of these (see Fig. 649) is the *Meganteris ovoides*, Sp. Eaton, formerly the *Atrypa elongata*, Conrad. The outline of this shell is a remarkably beautiful oval. Judging from the pits in the sandstone, it was an abundant inhabitant of the bed of the Appalachian ocean in the Meridian period, to which it was restricted.

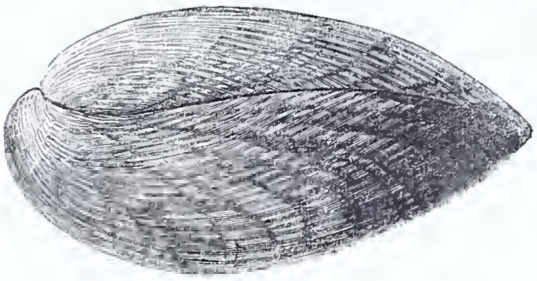


FIG. 649.—Meganteris ovoides.

Another brachiopod of this rock is the *Spirifer arenosa*, Conrad; a large species, having a rather ample hinge area, and 16 or 17 strong ribs (see Fig. 650).

The most remarkable fossil of the formation is *Atrypa unguiformis* (see Fig. 651), found usually as an internal cast, displaying in part the structure of the animal which inhabited the shell. It gets its name from a fancied resemblance to the imprint of a hoof.

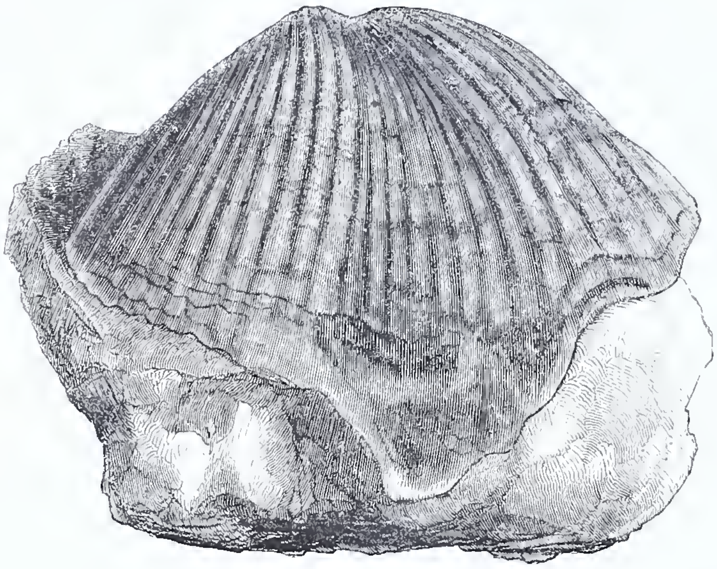


FIG. 650.—Spirifer Arenosa.

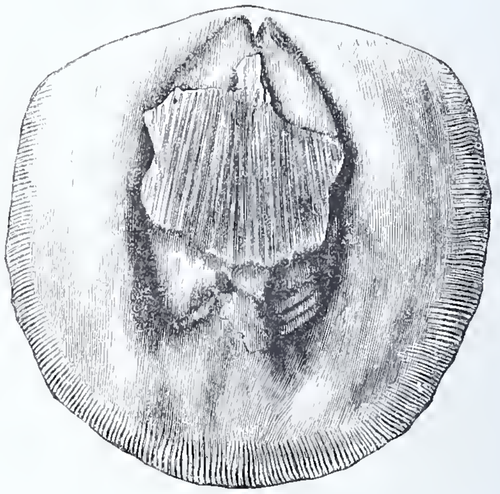


FIG. 651.—Atrypa unguiformis.

ORGANIC REMAINS OF THE POST-MERIDIAN STRATA.

The next Appalachian formation, the Post-meridian series, may scarcely be called a Pennsylvanian deposit, entering only the eastern border of the State a short distance, near the Delaware Water-gap. Its most characteristic fossil in that quarter is a singular sea-weed or fucus-like impression called in the New York Survey the *Fucoides cauda galli* (see Plate XXI. Fig. 1.), from its resemblance to the tail of a cock. It characterises the sandy calcareous shale which intervenes between the Meridian sandstone and the Post-meridian Onondaga limestone.

ORGANIC REMAINS OF THE CADENT STRATA.

The Cadent slates and shales of Pennsylvania entomb a multitude of rather imperfectly-preserved organic remains, for the most part in the condition of casts, from which I shall select several of the more characteristic species.

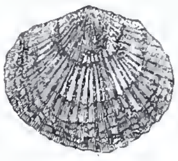


FIG. 652.—Atrypa limitaris.

FIG. 653.—Orbicula minuta.

Beginning with those of the Cadent older or Lower Black Slate, we find the most common of all its Mollusca to be the *Atrypa limitaris*, Vanuxem (see Fig. 652), a compressed nearly circular shell, with regularly-radiating equal ribs. It abounds in some of the calcareous or cement beds. A second common brachiopod is *Orbicula minuta*, (see Fig. 653). Another very common form is the *Orthoceras subulatum* (see Fig. 654), a delicate Cephalopod, always found flattened and crushed, and seldom revealing the distinctive septa. Along with this last we often find small, pointed leaf-like impressions, possibly the leafy appendages of Lepidodendron, which, we shall presently see, is unmistakably present in the Upper Black Slate.

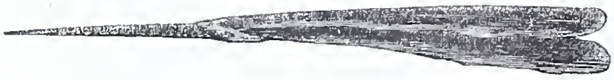


FIG. 654.—Orthoceras subulatum.

Among the humbler animal forms of the Cadent shale is a coral, the *Cyathophyllum turbinatum* (see Fig. 655). Of the Mollusca there are a few species of *Polyzoa:* one here shown belongs apparently to the *Escharadæ* (see Fig. 656). Of the conchiferous molluscs, the *Avicula decussata* (see Fig. 657), *Modiola concentrica* (see Fig. 658), *Avicula* *flabella* (see Fig. 659), *Microdon bellastriata* (see Fig. 660), *Orthonota undulata* (see Fig. 661), and a small Avicula (see Fig. 662), like *A. œvis* of Hall, are apparently the most common. Another Avicula of a very different type is here figured (see Fig. 663). To these we may add a Posidonia (perhaps an *Estheria*), here figured (see Fig. 664).

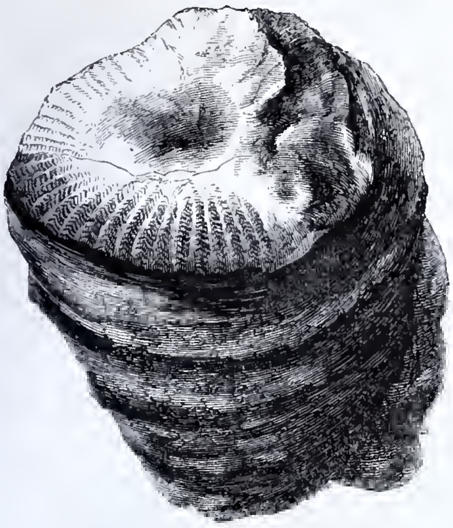


FIG. 655.—Cyathophyllum turbinatum.

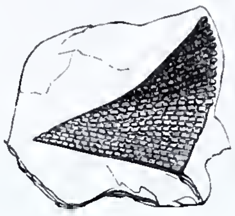


FIG. 656.—Fenestella ?

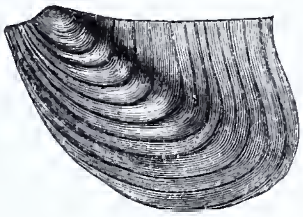


FIG. 657.—Avicula decussata.

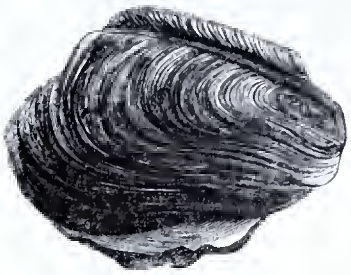


FIG. 658.—Modiola concentrica.

But the most abundant of the Mollusca are the Brachiopoda. Among these I would call attention to the following, as useful for identifying the formation: *Strophomena crenistria* (see Fig. 665), and *Strophomena demissa*, (see Fig. 666); *Spirifer spiriferoides ;* *Atrypa concentrica*, not unlike the *Terebratula concentrica* of Bronn (see Fig. 667); *Spirifer mucronata* (see Fig. 668); *Delthyris medialis*, Hall (see Fig. 669), and *Delthyris congesta* (see Fig. 670); *Atrypa aspera* of Schlotheim (*A. spinosa*), Hall (see Fig. 671), a European shell; and *Tropidoleptus carinatus*, Sp. Conrad (see Fig. 672). A large and beautiful shell, occasionally met with, is the *Delthyris granulifera* (see Fig. 673), proposed by Mr Hall as the type of the genus Tropidoleptus.

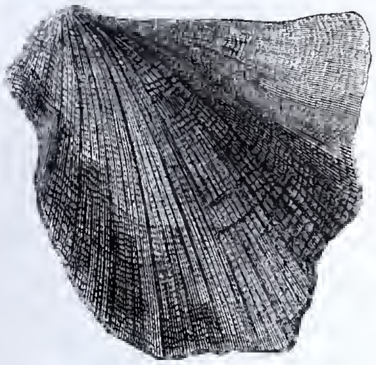


FIG. 659.—Avicula flabella.

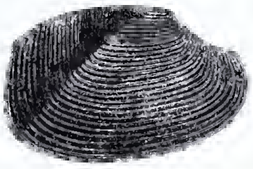


FIG. 660.—Microdon bellastriata.

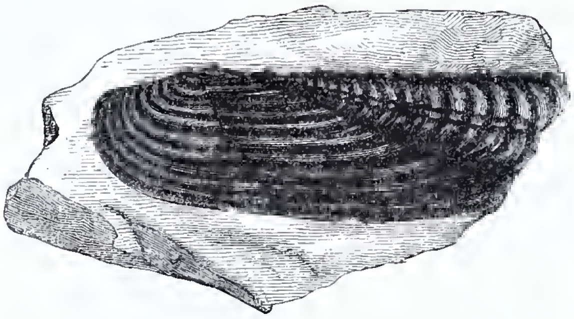


FIG. 661.—Orthonota undulata.

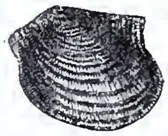


FIG. 662.—Avicula.

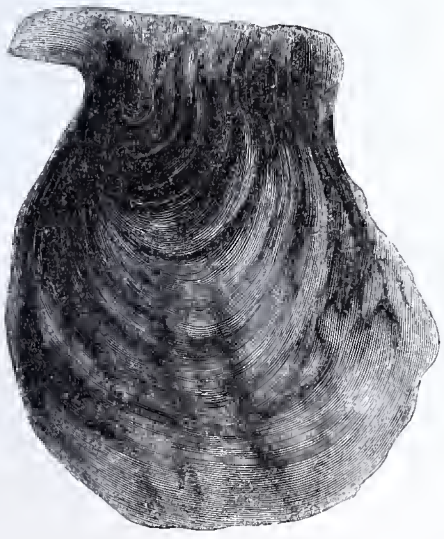


FIG. 663.—Avicula.

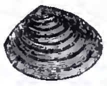


FIG. 664.—Posidonia or Estheria.

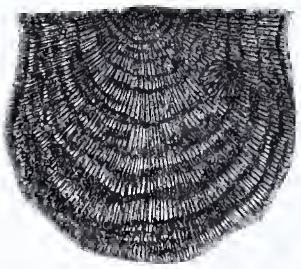


FIG. 665.—Strophomena crenistria.

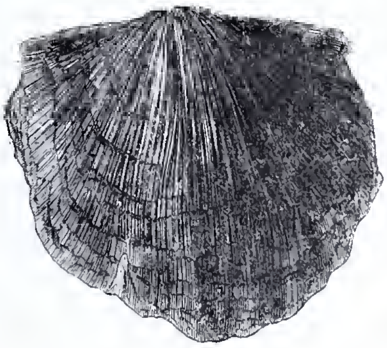


FIG. 666.—Strophomena demissa.

Another abundant brachiopod is the *Productus hirsutus* (see Fig. 674), covered with closely-set hair-like spines. This, and one or two other Producta, are interesting links between the Cadent and the Carboniferous formations, the genus Productus being regarded as eminently characteristic of the latter. Ascending into the Cadent upper black slate, we encounter a repetition of some of the smaller species of the Cadent lower black slate, and among them well-developed specimens of an air-breathing plant, a *Lepidodendron*, of which I here

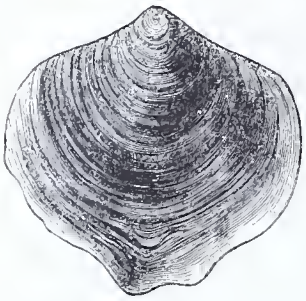


FIG. 667.—Spirifera spiriferoides.

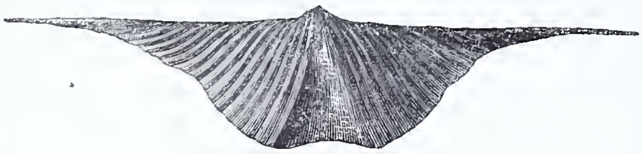


FIG. 668.—Spirifer mucronata.

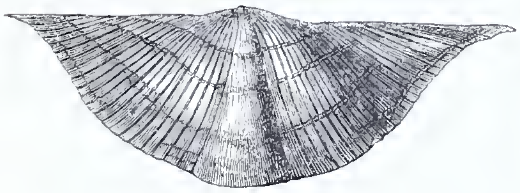


FIG. 669.—Delthyris medialis.

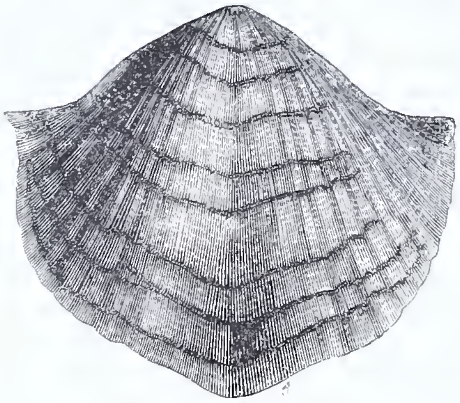


FIG. 670.—Delthyris congesta.

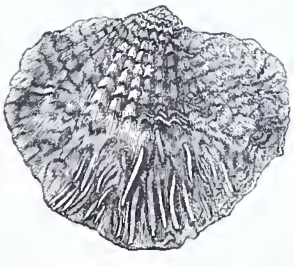


FIG. 671.—Atrypa aspera.

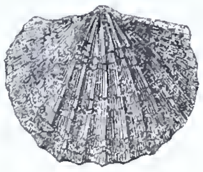


FIG. 672.—Tropidoleptus carinatus.

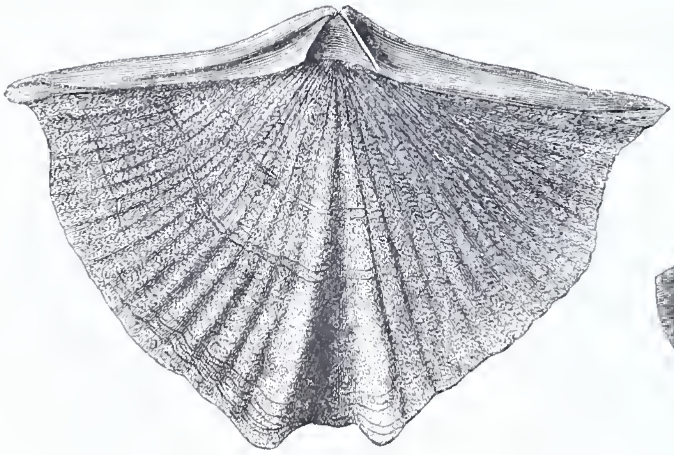


FIG. 673.—Delthyris granulifera.

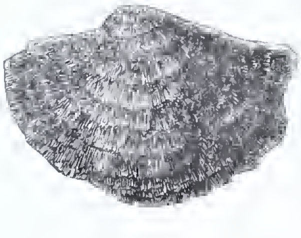


FIG. 674.—Productus hirsutus.

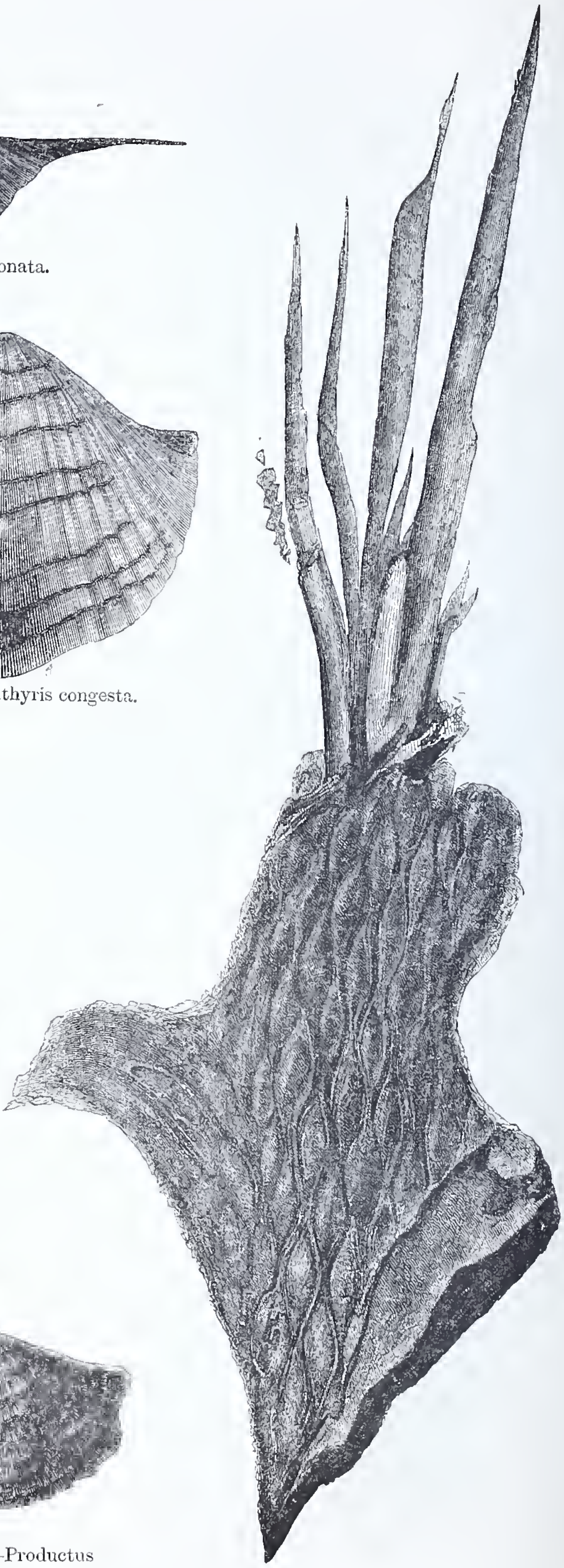


FIG. 675.—Lepidodendron primævis.

present a figure, (see Fig. 675), representing a fragment of a bifurcating stem, surmounted by its grass-like leaves, from a locality of these fossils at the mouth of Standing Creek, just E. of the town of Huntingdon. I propose to call it *Lepidodendron primævis*, as signifying the early age at which one of the main coal-producing types of vegetation made its appearance.

Curiously enough, we find in the very same layers of fissile black slate, between which the Lepidodendron has been flattened and preserved as in the leaves of an herbarium, beautiful specimens of a delicate shell, the *Goniatites interruptus ?* (see Fig. 676), belonging to a type of Molluscs supposed to have inhabited, if not the sea itself, the brackish waters of its margin.

The other associates of these fossils, an Orbicula, two Lingulæ, and an Atrypa, imply the same thing—a deposition of the dark carbonaceous slate beneath waters open to the sea. We may conjecture that the part of the ocean imbedding these remains was very shoal, and that a low marshy coast supporting the lepidodendron, and collecting the carbonaceous matter, could not have been far distant. One of the most expressive facts bearing upon the marvellously vast and uniform features of the physical geography of the Appalachian basin in some of its periods, is the occurrence of the Cadent lower black slate from Tennessee, N.E. to New York, and from New York W. to Illinois, and its reappearance far to the N.W. in British America, along the McKenzie River, even to the Arctic Sea.*

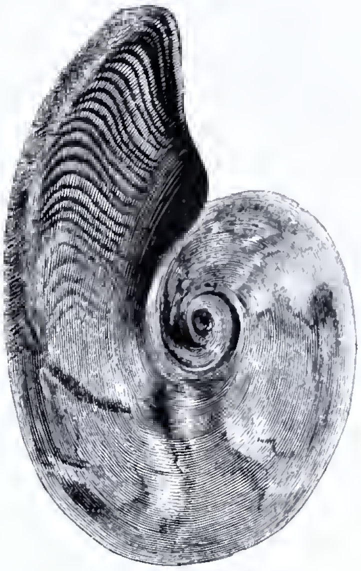


FIG. 676.—Goniatites interruptus (?).

The most abundant trilobite of the Cadent series in Pennsylvania is the *Calymene bufo*, Green.

Another quite common trilobite, *Homalonotus* (*Dipleura*) *Dekaii.* As far as known, this species is restricted to the Cadent shales. The *H. delphinocephalus* of the Niagara group of New York has not been found in Pennsylvania. No fish-remains have been discovered in the Cadent strata of Pennsylvania.

ORGANIC REMAINS OF THE VERGENT SERIES.

This great formation, notwithstanding its thickness, is so uniform in composition, and so generally destitute of calcareous matter, that its organic remains are inferior in their abundance to those of the much thinner Cadent series beneath it.

Of Plants, it contains, besides several fucoids, chiefly characteristic of the lower member or Vergent flags, occasional specimens of what appears to be a *Lepidodendron* (see Fig. 677). This is apparently the same fossil which is figured in the *Geology of New York*, Part IV., by Prof. Hall, under the name of *Sigillaria Chemungensis.* This confessedly terrestrial plant is interesting as forming one of a series of steps through which we trace the gradual advent of that remarkable flora which flourished in such exuberance in the later Carboniferous or Coal period.

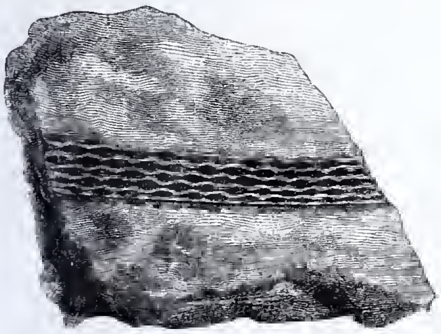


FIG. 677.—Lepidodendron.

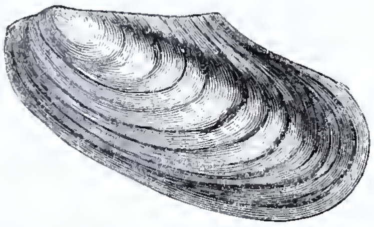


FIG. 678.—Avicula damnoniensis.

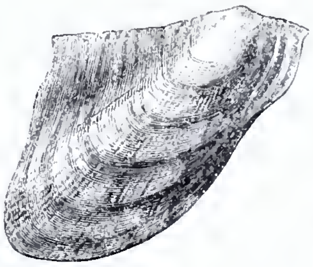


FIG. 679.—Avicula.

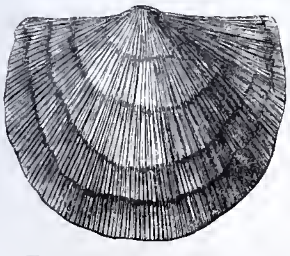


FIG. 680.—Strophomena Chemungensis.

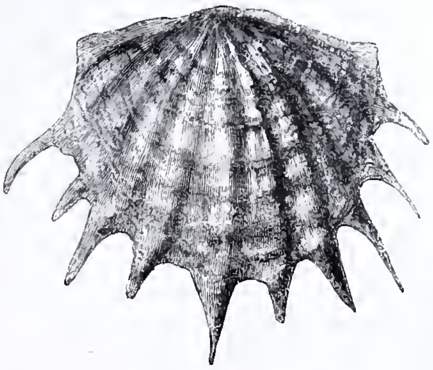


FIG. 681.—Atrypa hystrix.

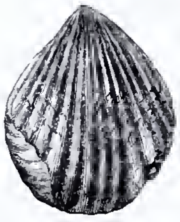


FIG. 682.—Atrypa eximia.

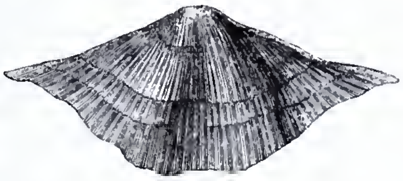


FIG. 683.—Delthyris cuspidata.

Among the conchiferous molluscs special to the Vergent formation are two or three Aviculas, as *Avicula damnoniensis* (see Fig. 678), a beautiful form characteristic of the Upper Devonian strata of Europe. Another species found high in the series (see Fig. 679) is somewhat common. I suspect it to be a new species, but do not presume to name it.

---

* See " Geology of the Hudson Bay Territories," &c., by A. K. ISBISTER, M.A.—*Quarterly Journal of the Geological Society*, vol. xi.

The most numerous shells of the formation are its brachiopods; one of these is the *Strophomena Chemungensis* (see Fig. 680.) A remarkable Atrypa, the *A. hystrix*, is distinguishable from every other of its genus, by the size of its ribs and the long spines which proceed from them (see Fig. 681). Another species is the *Atrypa eximia*, Hall (see Fig. 682). Some of the Spirifers or Delthyri of this formation are of unusual size; a common species of the genus is *Delthyris cuspidata* (see Fig. 683).

ORGANIC REMAINS OF THE PONENT ROCKS.

The Ponent series (Catskill group), like most deposits of red sandstone and red shale, destitute of calcareous matter, are very deficient in organic remains. One may search through large tracts of it in Pennsylvania, and not meet with a solitary fossil. This is especially so in its outcrops in the Appalachian chain. Near the N. border of the State, some of its lower layers do contain a few relics of extinct life; by far the most interesting of these are the bones and scales of two species of fishes of the genus Holoptychius, discovered near the Tioga River by the engineers constructing the Tioga Valley Railroad. The reader will find a brief description of these, with figures, in the *Geology of New York*, Part IV., page 281. In the Appalachian chain we occasionally meet with traces of vegetation in the upper strata. One of these plant-impressions is the fern-like form here represented (see Fig. 684); it bears some resemblance to the genus Noeggerathia, but its characters are too vague to enable us to settle its affinities. Another curious plant, equally obscure in its relationships, represented on Plate XXII., is now and then met with: see the note upon it kindly furnished me by Professor Balfour of Edinburgh, at the end of the chapter on Organic Remains.

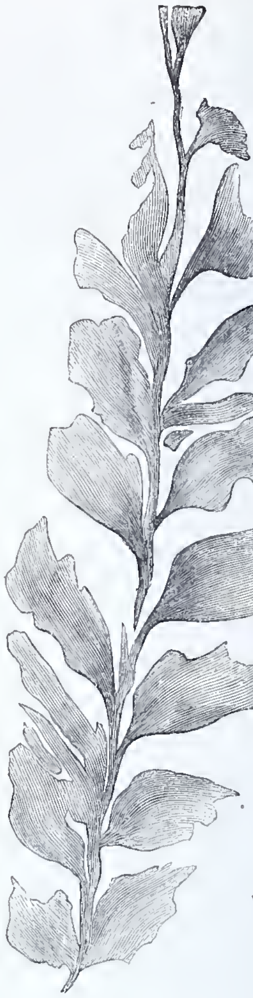


FIG. 684.—Ponent Fern?

ORGANIC REMAINS OF THE VESPERTINE AND UMBRAL STRATA.

One of the least fossiliferous of the formations of the Palæozoic system in Pennsylvania is the Vespertine sandstone. Consisting as it does throughout its outcrops in the Appalachian chain of pebbly grits, argillaceous sandstones, and sandy shales, all destitute of the carbonate of lime, so essential to the marine organisms susceptible of fossilisation, it is absolutely deficient in molluscan or other types of aquatic life. Towards the N. border of the State, one or two thin layers of partially-calcareous rock do appear in it, and these contain a few obscure casts of what seem to be bivalve shells. Adjoining the anthracite coal-fields, this deposit, somewhat resembling the conglomeritic group at the base of the Coal-measures, presents a further analogy to the true coal-formation, in possessing some vegetable fossils identical in their generic characters with those which are distinctive of the true coal strata. These belong chiefly to the fern-like genus Noeggerathia and to the coal-producing genera Sigillaria and Lepidodendra. The most common Noeggerathia is *N. obtusa*, Lesquereux, figured on Plate I., fig. 11, among the fossils of the coal-formation; it occurs likewise in the Ponent rocks, the lowest position in which we have found the genus. The most common air-breathing plants are, however, the Lepidodendra; all of these hitherto seen have comparatively slender stems, and are characterised by the smallness of their leaf scars.—(See Plate XVI., fig. 2, of the fossils of the coal-formation). Lepidodendra of this type are to be found in the Vespertine formation, all along the Appalachian chain to South-west Virginia. Our coloured figure, Plate XXI., fig. 2, represents another specimen. Among the upper beds of the formation in the gap of the Mahoning Mountain at Mauch Chunk, there occurs, associated with the Lepidodendron, a small Stigmaria, the *Stigmaria minuta*, Lesquereux.—(See Plate XVI., fig 1, and Mr Lesquereux's description, in his Essay on the Fossil Plants.)

It is an interesting fact, that the small-scarred Lepidodendra of the Vespertine formation are represented by a very similar group in the lower carboniferous rocks of Great Britain and Ireland, furnishing an argument, independent of that from their stratigraphical position, for placing these two respective formations upon nearly the same horizon in time.

The only organic remains ever met with in the Umbral red shale of our E. coal-fields, are some rare impressions of a large plant-like form, discovered by us in the valley immediately S. of Sharp Mountain, at Pottsville, and in a few corresponding localities. This imprint upon the red sandstone has often the aspect of a large fleshy leaf, curiously corrugated, as if it had been crumpled, while in a flaccid state, by compression beneath a newly-deposited load of sediment. Each leaf-like portion exhibits a raised rib like an obscure rachis, but in other respects it bears a general likeness to some tribes of the Algæ, or Sea-weeds. Professor Balfour has kindly favoured me with a note upon it (see end of chapter on Organic Remains).

We sometimes find associated with this feather-like plant another marking in the rock, which traverses the strata perpendicularly, and branches downward like a root, and which, from its generally occurring in the same layers with the flattish, fucus-like impression, we may conjecture to have been its actual root. In one or two instances this root-like form has been seen to proceed from a large rudely-spherical body of similar structure, impressed on the surface of the same layer of red sandstone which contained a quantity of the flatly-expanded supposed sea-weed; a further evidence of their being related as the upper and lower parts of the same vegetable. The leaf-like portion is sometimes between 2 and 3 feet long, and several inches wide, and the impressions regarded as its root are of the length of some inches.

Amid a very general paucity of animal remains, the Vespertine formation contains some very interesting vestiges of animated creatures in the shape of footprints. The relics of this class hitherto brought to light have only been met with at the S. outcrop of the formation, in the neighbourhood of Pottsville. One species, the largest, was discovered in 1849, by Isaac Lea, Esq. of Philadelphia, on a slab of Umbral red sandstone, also impressed with the wave-like structure called "ripple-mark." It was stratigraphically situated about 700 feet below the top of the formation, or its contact with the base of the coal-formation just S. of Sharp Mountain, at Mount Carbon. These footmarks, of which there are four in number, alternately right and left footed, forming a line of nearly a yard in length, have been attributed by Mr Lea to a Saurian reptile which he has called *Sauropus*.

About 1500 feet lower in the formation, or farther S. in the same locality, the Geological Survey brought to light another species of footprints of much smaller dimensions; and soon afterwards two other varieties, at a spot not far S. of the West-Branch Gap in Sharp Mountain. The largest of the three species, identical apparently with the Sauropus of Lea, consists of footprints, each about 2 inches in diameter, alternately right and left footed, and quadrupedal, with the fore and hind feet of nearly equal dimensions; the length of stride being about 9 inches, the straddle between the right and left footsteps nearly 4 inches, and the imprints of the hind-feet but little behind those of the fore-feet. A somewhat indistinct grooving of the surface of the stone, in two or three places centrally between the two rows of footsteps, suggests that the creature leaving these marks may have dragged a tail behind it, and the whole aspect of the impressions is suggestive of an animal allied rather to the Saurians than to the Batrachian or Chelonian reptiles. All of the three species of footmarks are quadrupedal, and all of them five-toed, and right and left footed, with an alternation also implying both fore-feet and hind-feet. In the smallest species, the toes are very divergent, like the fingers of the human hand firmly outspread upon a table. Each footprint is about half an inch in diameter, and the length of stride is from 2 to 4 inches. No traces of reptilian bones were discovered with these impressions, nor indeed in any part of the formation. I have invariably noticed that the surfaces bearing these supposed reptilian impressions, which considerations of economy have compelled me to omit engraving, exhibit various indications of having been exposed to the air in a wet state at the time the imprints were formed. They are always at the incohering partings between easily-separating beds of sandstone; and the indented surface is glazed with a fine slimy clay, such as retreating turbid water leaves behind it: the scaling off of this coating of clay soon obliterates the smaller footprints. These glazed surfaces are furthermore impressed with delicate watermarks and groovings, such as water trickling down a slimy or wet sandy beach always produces. In some instances we see them imprinted with the markings called "rain-spots;" and in rarer cases they show cracks filled with sand, such as geologists are wont to attribute to shrinkage in mud from the sun's heat. So exclusively are the footprints confined to these glazed and seemingly half air-dried surfaces, that it is in vain to look for them by splitting open the cohering layers of the sandstone, for they occur only where the beds spontaneously separate. All the associated phenomena confirm the inference drawn from the footprints themselves, that the creatures which left them were air-breathers in their organisation.

The annexed cut represents a locality where the sun-cracks above alluded to are exposed in a roadside quarry, near the village of Dauphin, on the Susquehanna (see Fig. 685). The shrinkage and cracking took place in a layer of slimy mud, now smooth red shale, and the cracks are occupied by sand sifted in at the strewing of the immediately overlying layer, which is one of red sandstone. Frost and weather have long since defaced the surface, which, when it was freshly uncovered many years ago, offered a very striking example of the phenomenon. No reptilian or other footprints were visible when we examined it.

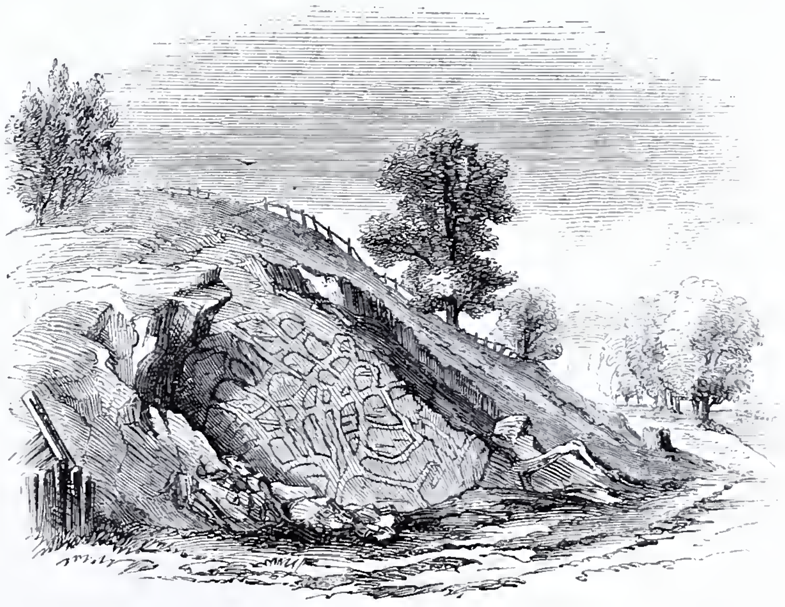


Fig. 685.

Upon some of the parting surfaces of the beds of the Umbral formation, we meet with curious corrugated impressions of the character shown in the accompanying figure (see Fig. 686). These are of various aspects, but the most common sort, that here illustrated, is about half an inch wide, and includes three separate bands of corrugation, the central strip having this feature on an exceedingly minute scale. One margin of the impression invariably shows a narrow sharp groove, 2 or 3 inches long, gradually diverging from the centre in a very gentle curve to a point outside of the edge of the corrugation. The whole impression looks like the trail left by some crawling mollusc, and we may fancy that the slender groove which is always on one side only, has been made by the edge or lip of the creature's shell, ploughing the mud or sand as it advanced. It is worthy of note, that these trails have not been seen upon the same class of surfaces as those imprinted with the footsteps, but upon partings in the strata which are more uneven and less glazed, and which look as if they had been covered with sediment while under water.

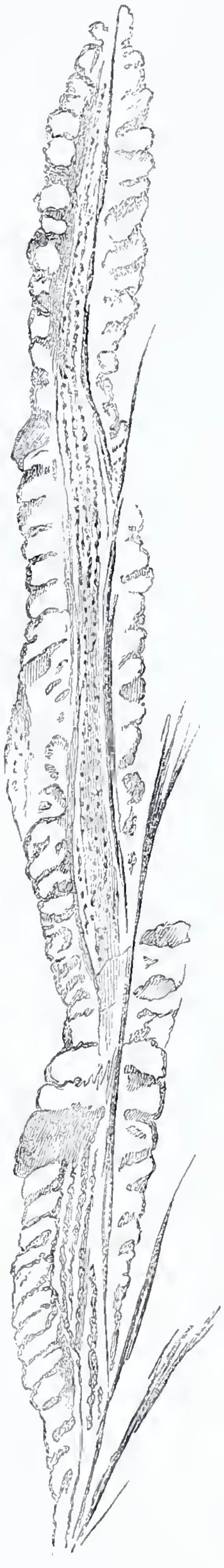


Fig. 686.—Trail of a Mollusc?

Trails of other patterns, some of them more sharply punctated than these now noticed, as if by the fins of fishes, are occasionally seen in the strata of some of the underlying formations; they are not infrequent in the lower and middle layers of the Vergent series, particularly on the Lehigh River, N.W. of the Lehigh Water-Gap, below Weissport.

No vestiges of reptilian life have been met with in Pennsylvania, nor indeed anywhere among the Appalachian formations, lower in the strata than the impressions above spoken of as occurring near Mount Carbon, and their horizon is about 2000 feet below the base of the Coal-measures, or upper Carboniferous series. As, nevertheless, the actual remains of reptiles have been found in Scotland, and elsewhere, in deposits of Devonian or old-red-sandstone date, or on the parallel of our Ponent strata, two formations lower than these in the Appalachian system, we are not entitled to look upon them as altogether the most ancient traces of reptilian life, and it is very probable that future geological researches will bring to light, if not the bones, at least the footprints of creatures of that class, even as low down among the strata as the Vergent series, where we meet with so many indications of air-breathing plants, shore-marks, trails of molluscs, and other proofs of the conditions compatible with the existence of those races.

That any races higher by an important interval in the scale of organic beings than the reptiles which have left their traces in the Carboniferous and Devonian strata, coexisted with them, must appear, I conceive, very improbable, when we reflect that no vestiges of any such have ever yet been met with, though we are assured by the reptilian footprints, and other independent evidences, that the physical conditions of the surface were every way favourable for the preservation of their tracks. The successive disappearance of the traces of the higher forms of life, as we recede into remoter geological times, is one of the clearest proofs which we can have of a progressive elevation in the scale of structure of the races successively created. The law of the successive appearance of the footprints is quite as conclusive as that of the parallel introduction of the actual skeletons and remains of the creatures themselves. It is perhaps of even more weight as precluding all discussion upon the differences of degree of destructibility of the bones or carcasses of the several classes of animals which peopled the ancient world. Some of the bird-tracks and reptilian footprints left on the once soft surfaces of the old rocks, are as clear and legible as any impressed yesterday on surfaces of moist mud or sand by the creatures of corresponding structure. Once bedded and sealed up, their preservation has been independent of the lapse of time. This law of a progressive rise in the footprints, like that so generally recognised in regard to the organic remains themselves, distinctly refutes the view taken by some disciples of the Huttonian theory of the earth's history, that, the higher animal forms being inhabitants of the land, we ought not to look for their remains in strata of marine or aqueous origin, but must suppose they were never entombed. But the negative evidence from footprints is of positive force when it appeals to appearances in the imprinted surfaces of the rocks, which show that they were exposed in a moist state to the air above the level of the waters, and in situations as accessible to mammalia as to birds,—in the instance of the Connecticut red sandstone, and in the case before us of the still earlier formations, as accessible to both mammalia and birds as to the reptiles which left their tracks upon them.

The only district within the State in which the umbral strata contain any actual organic remains of the extinct species themselves, is the tract commencing in Cambria County, and extending through Somerset County to Maryland. Here the formation assumes a more calcareous character than it possesses anywhere to the N.E., and even admits a thin stratum of limestone, which, expanding towards the S.W. and W., becomes the Great Carboniferous Limestone of the Southern, Central, and Western portions of the Appalachian basin. This limestone, especially in the districts of its full development, abounds in fossil remains of a marine type—zoophytes, echinoderms, and molluscs—many of them analogues of the fossils distinctive of the carboniferous limestones of Europe, to the horizon of which it seems to approximate. Among the few fossils imbedded in this rock in Somerset County, where it is thin and near its ancient Eastern limit, one of the most common is a *Productus*, with a comparatively short hinge, and great elongation of the dorsal valve. I think it is equally typical of this stratum in the Western States, but I have not been able to learn the specific name there conferred upon it. (See Fig. 687).

The beautiful fossils called *Pentremites*, a group of stemless echinoderms equally distinctive of the Umbral or carboniferous limestone, are rarely met with in Pennsylvania; but the species here shown does occur, and is very common, farther S. in Virginia. (See Fig. 688).

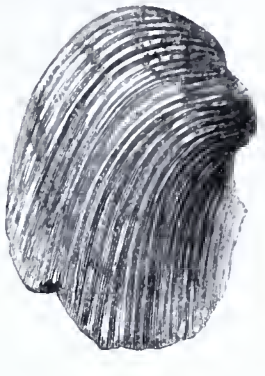


FIG. 687.—Productus.

ANIMAL REMAINS OF THE COAL STRATA OF PENNSYLVANIA.

The Coal-measures of Pennsylvania, except near the W. side of the State, possess but few species of animal remains; the Anthracite-measures almost none at all. This paucity of molusca and other aquatic forms is attributable to causes already amply explained—the generally littoral or land-derived character of the sediments, and corresponding scarcity of calcareous matter in the shales. Until very lately the anthracite fields had failed to disclose a single fossil-shell, but in the summer of 1857, my nephew, W. B. Rogers, jun., discovered the casts of two or three (an Avicula? and a Tellinomya?) in coal-slate near the mouth of the Ravensdale tunnel.

The limestone layers and beds of calcareous shale of the bituminous coal-fields of the Western counties contain some well-preserved species; among them a small *Avicula*, here shown (see Fig. 689), and another shell, apparently a new species of Nucula? (see Fig. 690), an ornamented *Pleurotomaria* (see Fig. 691), and a Nautilus, apparently *N. decoratus*, Cox (see Fig. 692), somewhat like the *N. tuberculatus*, Sowerby. This last shell is often seen in a fossiliferous layer in the cliffs of the Monongahela River, opposite Pittsburg. Another mollusc of the Coal-measures, seen occasionally in the same strata, but more common in Western Virginia, is the *Goniatites Nolenensis*, Cox, a species found also in Kentucky. We likewise meet sometimes with a delicate little elliptical *Lingula* (see Fig. 693), especially interesting from the position in which it is usually found.

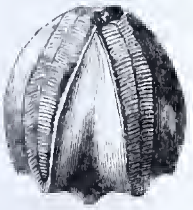


FIG. 688.—Pentremites.

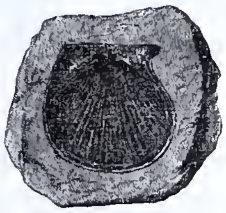


FIG. 689.—Avicula.

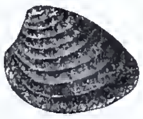


FIG. 690.—Nucula?

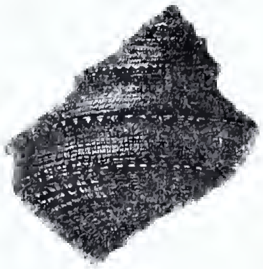


FIG. 691.—Pleurotomaria.

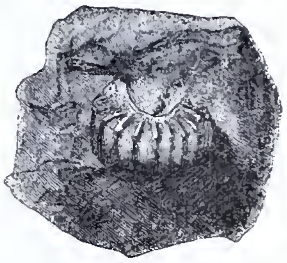


FIG. 692.—Nautilus decoratus.

FIG. 693.—Lingula.

It is most apt to occur in carbonaceous fissile black-slate—indeed it is seldom seen but in the roof-slate of a bed of coal. The specimen here figured is from this position, just above a coal-seam at Nelsonville, Ohio; and I have met with it in the same position above a coal-bed in Mercer County, in Pennsylvania. I have also seen a Lingula, apparently the same species, in the black roof-slate of a coal-seam on the E. slope of the Cumberland Mountain, in Tennessee. As it is well known that some of the living Lingulæ inhabit shallow waters, the occurrence of these remains so immediately above a stratum which was demonstrably formed in contact with the air, need not surprise us, if we adopt the explanation of the origin of the coal strata presented in the foregoing pages, and suppose the coal-bed overlaid by the Lingula slate to have been a level savannah bordering the sea, and to have quietly sunk beneath the level of the waters, enabling the marine organisms to take up their abode above it.

The Western Coal-measures contain a large Spirifer, here represented (see Fig. 694). It is of a type often met with in the carboniferous limestone.

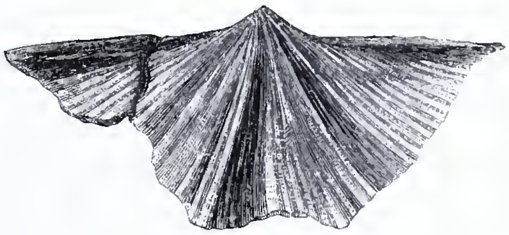


FIG. 694.—Spirifer of the Coal Strata.

Of the remains of vertebrated animals the coal strata of Pennsylvania have hitherto revealed but few traces. No well-identified fish-remains have yet appeared; but some years ago some interesting reptilian footprints were found by Dr King of Greensburg, Westmoreland County, on a slab of sandstone of the coal-formation in the neighbourhood of that town. These were subsequently examined by Sir Charles Lyell, who makes the following mention of them: "The foot-marks were first observed standing out in relief from the lower surface of slabs of sandstone, resting upon thin layers of fine unctuous clay. One of these masses displays, together with footprints, the casts of cracks of various sizes, referred to the drying and shrinking of mud, and the subsequent pouring in of sand into open crevasses. No less than twenty-three footsteps were observed by Dr King in the same quarry before it was abandoned; the greater part of them so arranged on the surface of one stratum as to imply that they were made successively by the same animal. 'Everywhere there was a double row of tracks, and in each row they occurred in pairs, each pair consisting of a hind and fore foot, and each being at nearly equal distances from the next pair. In each parallel row the toes turned, the one set to the right, the other to the left. In the European Cheirotherium both the hind and fore feet have five toes, and the hind foot is about five times as large as the fore foot. In the American fossil the posterior foot is not even twice as large as the anterior; and the number of toes is unequal, being five in the hind and four in the anterior foot. In this, as in the European Cheirotherium, one toe stands out like a thumb. The American Cheirotherium was evidently a broader animal than the European. We may assume that the reptile which left these prints on the ancient sands of the Coal-measures was an air-breather, because its weight would not have been sufficient under water to have made impressions so deep and distinct."

NOTES ON THE BEYRICHIÆ AND LEPERDITIÆ OF PENNSYLVANIA.

By T. RUPERT JONES, Curator, Geological Society of London.

I am indebted to my friend T. Rupert Jones, F.G.S. of London, for the following very clear descriptions of the species of Beyrichiæ and Leperditiæ, found by the Survey in Pennsylvania. The reader will see an interesting paper, on nearly all the known North-American species of these obscure genera, which Mr Jones has studied with great success, in the *Annals and Magazine of Natural History* for April 1857.

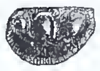


FIG. 695.—Beyrichia Maccoyiana.

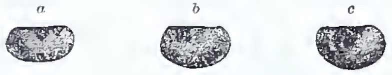


FIG. 696.—Beyrichia Pennsylvanica (different stages of growth).

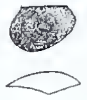


FIG. 697.—Leperditia ovata.

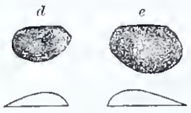


FIG. 698.—Leperditia Gibbera, *var.* Scalaris.

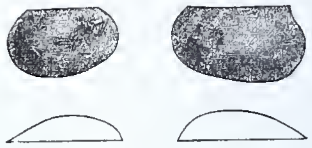


FIG. 699.—Leperditia Pennsylvanica.

BEYRICHIÆ.

1. The species of Beyrichiæ (Fig. 696, *a b c*) which occurs in such numbers as to constitute the chief material of the limestone bands of the Scalent marls of Pennsylvania, is new, and presents several varying forms, probably indicative of successive conditions of growth. Three of these I have selected for illustration, but intermediate forms frequently occur. This is a bisulcate Beyrichia, having general resemblances to some other forms, but distinct specific characters, which latter are chiefly found in the proportion of the surface-lobes of the valves and their finely-sculptured ornament. I have named it *B. Pennsylvanica.*

There are two individuals of apparently a smooth variety of this species, showing a strongly lobed surface (as in Fig. 696 *c*), in the greyish limestone from near Barre Forge, where it is associated with *Leperditia Pennsylvanica.*

2. *Beyrichia Maccoyiana* (Fig. 695), a species of rather rare occurrence in the Upper Silurian limestone of Sweden (strewed as boulders over parts of Prussia), occurs in a piece of the Beyrichia limestone from the marls of the Scalent series, where it is of rather a larger size than the European specimens, and, excepting its delicate marginal frilled rim, is in good preservation.

LEPERDITIÆ.

1. A single specimen, *L. ovata* (Fig. 697), in the dark-grey Auroral limestone from Potter's Fort, Penn's Valley, affords good evidence of a species of Leperditia, characterised by a simplicity and ovateness of form not present in any other known to me.

2. *L. Pennsylvanica* is the name imposed by me on a handsome species in the grey limestone from near Barre Forge. It has relations with *L. Balthica* and *L. Arctica*, but differs from both, chiefly in its relative narrowness and great convexity (Fig. 699). It is an important species, in my esteem, as being probably a geographical representative of its European and Arctic allies.

3. A variety of *L. Gibbera*, a species founded by me on good specimens from Beechy Island, occurs in the black limestone of the Scalent series, in good condition, showing a want of the surface-pittings which the type possesses, and a smaller dorsal hump on its left valve (Fig. 698, *d e*).

Casts of the same variety (*L. Gibbera* var. *Scalaris*) occur also in the grey "Waterlime" rock of Williamsville (Museum Geol. Soc.)

A thin seam of hard grey limestone, half an inch thick, from a rather higher horizon than that of the black limestone, has its surfaces thickly beset with badly-preserved valves of Leperditia, apparently of the same variety as the one last described.

These Pennsylvanian species are important additions to the crustacean fauna of the Lower Palæozoic age, and enlarge the number of the North-American bivalved Entomostracæ, of which I now know twenty-three chief forms, besides minor varieties. These are either mentioned or described in the *Annals of Natural History* for April 1857. There are four other forms mentioned by Professor James Hall (*Palæont. New York*), which I have not yet met with, and of which it is difficult to form an opinion by the figures given.

FOSSIL PLANTS OF THE COAL STRATA OF PENNSYLVANIA.

The following new species of fossil plants, one hundred and ten in number, are some of the results of a systematic investigation of the fossil flora of the carboniferous strata of Pennsylvania and the adjacent coal-fields of Ohio and Virginia, undertaken a few years ago by my able assistant in this department of the geological survey of Pennsylvania, Leo Lesquereux, Esq., formerly of Switzerland, now of Columbus, Ohio.

By far the greater part of the specimens were collected by himself. A few of the new species were first seen and studied by him in the rich local cabinets of Mr Clarkson, of Carbondale, and of the Rev. W. Moore, of Greensburg, to whom our best thanks are due for their liberality in thus opening their collections for the description of what was new. Many of these hitherto undescribed forms were discovered in the slates, associated with the beds of anthracite in the coal-fields of Eastern Pennsylvania, which, compared with the bituminous Coal-measures of Western Pennsylvania, appear not only to contain a greater variety of species, but to present them in a condition of more perfect preservation for study.

The new species here briefly described by Mr Lesquereux constitute about one-half of the total number of well-defined forms hitherto detected by him in the Coal-measures and lower carboniferous rocks (the Vespertine series) of Pennsylvania ; more than one hundred of the two hundred and twenty species examined by him proving to be entirely identical with species already recognised in the European coal-fields, and some fifty more of them showing differences so slight, that a fuller comparison with better specimens may result in their identification likewise. As a further evidence of the near affinity of the North-American to the European fossil flora of the carboniferous age, he has remarked, in the course of his investigations, that even these new species, which seem restricted to this continent, are every one of them in close relationship with European forms. It deserves mention, moreover, that the commonest European species are likewise the most common American ones.

A future comparison of the fossil plants of the several broad coal-basins of the United States, in their order from E. to W., will probably disclose a corresponding reduction in the number and variety of the species,—a view already suggested by their relative paucity in the bituminous coal-fields of Western Pennsylvania and Ohio, as measured against their abundance in the anthracitic basins.

Wherever I have studied either the anthracite fields or the great Appalachian basin, I have remarked that the lower or " White Ash " division of the Coal-measures gives indications of more violent and frequent disturbances of level in the surface at the time of the deposition of the strata than are noticeable in the composition of the upper or " Red Ash " part of the formation. Among the proofs are, more abrupt and frequent alternations of coarse and fine deposits, more diversified and rapid changes in the thickness, composition, and arrangement of the strata, both of the mechanical deposits and the life-derived beds of coal, and the far greater mutability and inconstancy of all those strata, even the most quietly deposited, within the same area or extent of outcrop. The lower strata of the anthracite Coal-measures are indeed remarkable for diversity in the coarseness of the sandstones, and for unsteadiness in thickness of the coal-beds themselves. Though these carbonaceous layers are the accumulations of once perfectly level sea-meadows, at successive depressions of the surface, it is evident, from their comparatively rapid thickening and thinning, and frequent coalescing and diverging, that the floors upon which they were collected were neither so wide as those which sustained the vegetation that resulted in the bituminous coal-beds, nor so uniform and gradual and horizontal in their slow movements of elevation and depression.

Commensurate with the more fluctuating size, and more restricted range of these lower coal-seams, is a greater inconstancy and diversity in their fossil flora. The more widely extended upper beds appear to exhibit a more limited specific vegetation, expanded over wider areas.

As far as our researches have gone, we notice that the lower strata, both in the anthracite measures and in the great Appalachian coal-field, abound in the larger species, especially in Lepidodendra, while the higher seams are characterised by the smaller *herbaceous species,* most generally the herbaceous ferns.

We conceive that the large proportion of species common to the coal strata of North America and Europe clearly establishes identity of age between the two deposits, and a close accordance, if not identity, in the geographical and climatal conditions prevailing at their formation. A yet closer agreement is noticeable between the species found in the several coal-fields of the United States. Indeed, so much alike are all the anthracite basins in their fossils, that Mr Lesquereux already recognises more than twenty familiar European species as common to these once continuously united coal-fields. It has been indicated above, that the two different groups of the coal strata of Pennsylvania, the lower or white ash, and the upper or red ash, are characterised by somewhat different species, though these more or less intermingle. Satisfied of this fact, of a general prevalence of certain forms in certain parts of the Coal-measures, we have aimed at carrying our inquiry a step farther, to ascertain whether or not any or all of the individual coal-seams themselves are separately recognisable by their fossil plants. Undoubtedly, in some of the broadly-deposited and uniformly-conditioned coal-beds and coal-slates of the W. bituminous coal-fields, a most striking prevalence is observed of the same species within the same layer, on comparatively wide areas; but amid the more regularly accumulated beds, of especially the lower or white-ash anthracite strata, formed on a less stable portion of the nowhere absolutely stationary crust, the inconstancy in the vegetation of even the same coal-seam is, for the most part, if not entirely, too great to permit an attempt to identify it by its fossils merely. Again, in some instances, coal-beds, which are demonstrably different, are almost absolutely identical in their fossils. This is the case with the "Gate" and "Salem" coals, near Pottsville. So strikingly alike are they in their vegetation, that Mr Lesquereux strongly inclines to regard them as but the detached parts of originally one sheet of coal, and to suspect that there is some error or obscurity in my section, which shows them to be separated by several hundred feet of strata, including a number of beds of coal. Of the validity of the proofs showing the so-called Salem vein to be a different coal from the Gate vein, and several stages higher in the series, there cannot, however, be any question, and the palæontological evidence for identity must therefore give way before the higher and more decisive demonstration, from superposition, of their difference in age.

Before entering upon the description of the new species, Mr Lesquereux presents the following introductory essay :—

GENERAL REMARKS ON THE DISTRIBUTION OF THE COAL-PLANTS IN PENNSYLVANIA, AND ON THE FORMATION OF THE COAL.

By LEO LESQUEREUX, Esq. of Columbus, Ohio.

The distribution of the fossil plants in the great coal-basins of America, especially in comparison with the vegetation of the same geological date in different parts of the world, is certainly one of the most interesting and important questions of geology. Before coming to any general considerations on this subject, it is necessary to look to the distribution of the fossil plants in the coal-basins of Pennsylvania,—apparently narrowing our point of view, but only to ascertain our premises, and to follow afterwards our deductions with more security.

The examination of the fossil plants of Europe has led many geologists to suppose that there had been some appreciable difference in the vegetation of each peculiar bed of coal, and that, by a close observation, it would be possible to identify the same veins of coal, or at least some of them, at two very distant points from each other. The geological formations are nowhere more continuous and homogeneous on larger surfaces, and nowhere better characterised, than in the great Mississippi Valley; and we think that a better confirmation of the opinion above alluded to could not be found anywhere else.

The anthracite basins of Pennsylvania, cut into many fields by the upheaval of the inferior strata, required first to be examined in its different sections, from its Eastern limits at Carbondale to its Western, to ascertain if those different sections following the vegetation are only parts of the same original formation.

But before enumerating the plants for a proof of the identity of the different basins, it is necessary to remark that we cannot expect to find in two different parts of any coal-field, a perfect concordance of all the species. It would be absurd to suppose that, at the same time, the same plants have been distributed on large surfaces exactly in the same proportion. As it happens in our own time, there are some plants of which the presence suffices to give a general feature to the vegetation. These are the plants most commonly found, whilst many others of which the distribution is not so general, cannot in any way, either by their presence or their absence, change the character of the whole. It is also not unnecessary to remark that, in a flora of which so few species have been preserved, and which is consequently so limited, the number of the characteristic species cannot be great. And it suffices that we meet a few of them, either in the different basins of anthracite, or in the different parts of the coal-basin, to justify our conclusion on the identity of those parts. It is well to recall to mind that such is the difference in the flora of the geological ages, that, in the nearest formation to the coal, or in the Permian period, there is scarcely a single species left which can be related to the vegetation of the coal.

We will then admit, as truly characteristic of the coal-formation of America, the following species :—1. *Asterophyllites equisetiformis*, Bt.; 2. *A. tuberculata*, Lindl.; 3. *Annularia sphenophilloides*, Ung.; 4. *Sphenophyllum Schlotheimii*, Bt.; 5. *Calamites approximatus*, Bt.; 6. *Noeggerathia*; 7. *Neuropteris hirsuta*, Lesq.; 8. *N. flexuosa*, Bt.; 9. *N. heterophylla*, Bt.; 10. *Dyctiopteris obliqua*, Bunb.; 11. *Sphenopteris Lesquereuxii*, Newb.; 12. *Alethopteris lonchitidis*, Sternb.; 13. *A. Serlii*, Göpp.; 14. *Pecopteris polymorpha*, Bt.; 15. *P. arborescens*, Bt.; 16. *Stigmaria ficoides*, Sternb.; with many species of *Sigillaria* and *Lepidodendron.*

Of these species, there are very few that have not been found in all the separate basins of the anthracite coal. To give only a few examples, *Neuropteris hirsuta*, *N. flexuosa*, *Sphenophyllum Schlotheimii*, are met everywhere. The first four plants enumerated above belong especially to the upper veins, open at Pottsville and around that place. They were found also at Shamokin, at Wilkesbarre, at Room Run mines, and at Tamaqua, in the lower Coal-measures. The genus *Noeggerathia*, as we shall remark farther on, pertains to the Vergent and Ponent (Devonian) formations. The same species of the genus were found below Pottsville, and in the Lehigh Gap at Mauch Chunk. No. 10, *Dyctiopteris obliqua*, Bunbury, is at some places very abundant, as at South Salem vein, opposite Port Carbon, and at Trevorton, behind a wall of Sigillaria. Nos. 11, 12, and 13, belong to the low beds, and are found at both extremities of the anthracite basin, at Room Run mines, Wilkesbarre, Shamokin, Trevorton, and also at Minersville and Tremont, with many identical species of *Sigillariæ* and *Lepidodendra.* Nos. 14, 15, 16, have been found also in all the localities of the anthracite basin.

But it would be useless to pursue this enumeration further, the identity of the different basins of anthracite becoming more evident by what we have to say upon the identity of their different beds.

It would, nevertheless, be going too far to promise an enumeration of the species belonging to each bed of coal or anthracite, for the fossil plants are found well preserved only in the highest and in the lowest strata of the American basins.

It is in the lowest strata of the coal and anthracite basins that we find the largest species of vegetables of the time, especially the *Lepidodendra*, with their bark, their fruits, and their leaves. On the roof-shale at Carbondale there is imprinted in one of the galleries the bark of a Lepidodendron, 2 feet in diameter, and 75 feet long. The same diameter is preserved in the whole length without any material diminution. On the contrary, the highest beds of the basin have the small and herbaceous species, and also the tree ferns; but more generally the herbaceous ferns, of which the leaves and the smallest branches have been preserved.

These highest beds crop out in the vicinity of Pottsville, and this place is particularly interesting for the great abundance of the fossil plants found in a good state of preservation at the Salem and the Gate veins. The relation of the vegetation of both these beds is so close, that after long and careful research, and though the dynamic (structural) geology does not agree with this conclusion, we are not able to point out a difference which will authorise a separation or a distinction between them. There is only—and this not at every place where these veins are worked—a slight difference in the colour of the roof-shales, which are grey at the Salem vein, and more black at the Gate. But this difference is scarcely appreciable. Following, then, our point of view, and taking the vegetable palæontology as the basis of our identification, we may assert that the South Salem vein, opposite Port Carbon, is the same as the Salem vein of the New Breaker; the same also as the Gate vein of Pottsville, and of Port Carbon, and the Lewis vein of Mill Creek. In all these veins the bed of coal, varying in thickness from 4 to 8 feet, is separated into two by a greyish shale 6 to 12 inches thick, which contains the great abundance of fossil plants of which we have spoken above: viz. *Asterophyllites*, *Annularia*, *Sphenophyllum*, and *Calamites*, are there especially abundant, with *Neuropteris hirsuta*, Lesq.; *Neuropteris heterophylla*, Bt.; *Neuropteris flexuosa*, and its varieties; *Odontopteris Schlotheimii*, Bt.; *Dyctiopteris obliqua*, Bunb.; *Sphenopteris latifolia*, Bt.; *Sphenopteris polyphylla*, Lesq.; *Pecopteris oreopterides*, Bt.; *Pecopteris arborescens*, Bt.; *Pecopteris cyathæa*, Bt.; *Pecopteris arguta*, Bt.; *Pecopteris unite*, Bt.; *Pecopteris loschii*, Bt.; *Sigillaria reniformis*, &c. The same plants are found in the same abundance, and on the same kinds of slates, up the Schuylkill Valley, at Port Carbon, New Philadelphia, and Middleport, where the vein is named Gate, and on the other side below Westwood, or West-Branch, and at W.-West Branch, where the vein is also named the Gate. Crossing the anthracite basin in a perpendicular direction, we find the same plants we have already mentioned as occurring at the South Salem, Salem, and Gate veins at Pottsville; at Lewis vein of Mill Creek, and at Norwegian; then N.W. of Westwood, where the vein is named Black vein, at Muddy Creek, between Pottsville and Tremont, and at the Tremont new vein. But though the plants above mentioned are the ones which give the true character to the vegetation of these strata, we will renew our observation on the general distribution of the plants, and show that each locality has also some species of plants which have not been found elsewhere. So at the Salem vein of the New Breaker of Pottsville we collected one fine *Cyclopteris fimberata*, Lesq.; *Cyclopteris Germari*, Göpp.; *Neuropteris delicatula*, Lesq.; *Neuropteris gibbosa*, Lesq.; and *Neuropteris dentata*, Lesq. The South Salem vein of Port Carbon has *Calamites decoratus*, Bt.; and *Calamites undulatus*, Bt.; *Annularia sphenophylloides*, *Neuropteris adiantites*, Lesq.; *Odontopteris squamosa; Sphenopteris flagellaris*, Lesq.; *Sphenopteris polyphylla*, Lindl.; and *Alethopteris muricat*, Göpp. At the Gate vein of Pottsville we have found *Neuropteris fissa*, Lesq., and *Neuropteris rotundifolia*, Bt.; *Neuropteris tenuinervis*, Lesq.; *Alethopteris urophylla*, Göpp.; *Pecopteris notata*, Lesq.; *Pecopteris concinna*, Lesq.; *Pecopteris decurrens.* The Gate vein of Port Carbon is particularly marked by the beautiful *Neuropteris Rogeri*, Lesq., found only at this place, as the same vein behind the hill E. of Port Carbon furnished us the remarkable *Alethopteris serrula*, Lesq. The Gate vein of New Philadelphia, like the same vein at W.-West Branch, is especially rich in the fruit of *Asterophyllites*—viz. *Asterophyllites tuberculata*, Lindl.; *A. lanceolata*, Lesq., and *A. aperta*, Lesq.; with many fine species of *Sigillaria*—as *Sigillaria reniformis*, Bt.; *Sigillaria Brardii*, Bt.; and *Sigillaria Sculpt*, Lesq. When at Muddy Creek and Middleport the same vein has also many beautiful *Sigillariæ*, as *Sigillaria fissa*, Lesq.; *Sigillaria Schimperii*, Lesq.; *Alethopteris distans*, Lesq., and *Neuropteris undans*, Lesq., &c. The vein named Black vein, N.W. of Westwood, is particularly marked by *Sphenopteris intermedia*, Lesq., and *Sphenopteris Gravenhorstii*; while the most different of all, the new vein of Tremont, has, for its peculiar plants, *Odontopteris crenulata*, Bt.; *Alethopteris marginata*, Göpp.; *Pecopteris ovata*, Bt.; *Pecopteris pennæformis*, Bt., &c.

The upper division of the Anthracite measures, characterised by the red colour of the ashes, contains, with the beds above named, a few veins with which we have become acquainted by many cross sections around Pottsville, and at Mill Creek. These are below Salem bed; the Tunnel vein, which has very black roof-slates, and is entirely covered with *Neuropteris hirsuta* and its stems, without any other plant, and the Black mine, of which the roof-slates are especially marked by the obsolete prints of *Asterophyllites*, *Annularia*, and *Sphenophylla*, in such a state of decomposition, that they are scarcely distinguishable, though very numerous. We have found this bed with the same slates at many places of the basin. Below it are the two Selkirk veins, which have no fossils at all, but of which the roof and bottom shales are impregnated with oxide of iron, becoming rusty coloured when they are exposed to the action of the atmosphere. Below the Selkirk vein is placed the Gate vein, which, as we have said, is the same as the upper bed—viz. the Salem vein.

Between this upper group (the red ash) and the lower one (the white ash), there is an intermediate one containing 4 or 5 veins of coal worked upon Mill Creek, and of which the slates, though very fine grey coloured, show no trace of plants. It is impossible to characterise them by the plants, but only by the colour and the nature of the slates.

But as soon as we come to the white-ash or lower strata the presence of large-sized fossils becomes apparent, first in the large quantity of *Stigmaria* abounding at the Diamond and Primrose veins, then in the *Lepidodendra*, and some large ferns which distinguish the Mammoth vein. This vein especially merits being mentioned for its peculiar flora. The roof-slate of grey colour, ordinarily charged with a great many nodules of iron, has generally preserved the impressions of the fossil plants in a very good state. While in the upper beds the predominance of small ferns was so striking that frequently on a single slate of about half a square foot we could observe as many as ten or fifteen species, here, on the contrary, there is scarcely any fern to be found, or if any, it appears to belong to the largest species. With the *Lepidodendra* and their fruits, found in great abundance at Wilkesbarre, Carbondale, Minersville, Tamaqua, Lehigh, and Summit Hill, the plant mostly found in these low veins is

Alethopteris Serlii, Bt., with its near relative, *Alethopteris lonchitidis*, Bt., and also *Neuropteris hirsuta*, Lesq., and *Neuropteris Clarksonii.* The fruit and leaves, or needles, of *Lepidodendron*—viz. *Lepidostrobi* and *Lepidophylla*, are also very abundant in the Mammoth vein of the anthracite, and as we did not find any specimen of these fruits anywhere in the other bed above, their presence, we think, may be relied upon as a true character of the lowest beds of the coal-basin in general.

Nevertheless, we find in these lowest strata the same variety as in the upper ones—viz. with a few characteristic plants, many which belong especially to some localities. Carbondale is particularly rich in trees. With nearly all the species of *Lepidodendron* that we have described, we have seen there also the largest number of well-preserved *Sigillariæ*, especially those of which, the bark being smooth and without ribs, we have a section nearly related to *Lepidodendron.* Wilkesbarre has plenty of *Lepidostrobi*, and some large *Pecopteris.* Room Run mines, *Alethopteris Serlii*, with the large *Cyclopteris orbicularis*, Lindl., and *Sphenopteris Lesquereuxii*, Newberry. Lehigh Summit abounds in *Sigillaria elegans*, Bt., and *Sigillaria Brochanti*, Bt. At Tamaqua we find again *Neuropteris hirsuta*, Lesq.; at Miner's Hill, *Alethopteris Serlii*, Bt.; at Shamokin the *Lepidostrobi*, and at Trevorton nearly the same flora as at Carbondale—viz. an abundance of large trees, and both *Alethopteris Serlii*, Bt., and *A. lonchitidis*, Bt. The only place where this low stratum does not afford a striking likeness by its flora with the other localities, is at the vein W. of Shamokin, near the creek, and behind the mill. We scarcely found there any *Lepidodendron*, but only the following species, which are worth mentioning: *Neuropteris hirsuta*, Lesq.; *Neuropteris tenuifolia*, Bt., with its *Cyclopteris elegans*, Lesq., *Sphenopteris glandulosa*, Lesq., *Alethopteris nervosa*, Göpp., *Callopteris Sullivanti*, Lesq. On these species we may remark that the first one is found everywhere from the base to the upper strata of the coal; that *Alethopteris nervosa*, which was certainly a very large fern, was found in the low beds only, and at many localities in the bituminous coal and anthracite basins; and that the fine *Callopteris Sullivanti*, which, by the form and direction of its leaflets, and by its general form also, is much like *Alethopteris Serlii*, ought to be admitted also as a very large fern. *Neuropteris tenuifolia*, Bt., resembles so much *Neuropteris flexuosa*, Bt., that they are scarcely distinguishable. The difference is here established by the age of the strata, as this last species belongs to the upper ones.

We have already alluded to the identity of the great Appalachian coal-field with the different anthracite formations, asserting that this identity is especially striking on a comparison of the flora of the different strata. The great Appalachian formation is divided in two principal groups, each containing ordinarily four veins of coal, and separated by strata of shale, sandstone, and limestone, from 300 to 500 feet thick. This is generally named the Barren formation, for though there are at some places some traces of coal and coal slates, there is not a good bed of coal in this whole group. The lowest bed of the basin rests on the conglomerate, and crops out at the Portage Summit, where we collected some *Lepidophylla*, especially with *Lepidophyllum brevifolium*, Lesq., and at Johnstown, where the black slates of the roof are charged with *Lepidostrobi*, and also with *Lepidodendron.* The only species found there, different from those collected at Wilkesbarre is a fine *Pecopteris velutina*, which looks like a large species. The same vein outcrops also at Cuyuhoga Falls, Ohio, where it abounds in *Lepidodendra*, *Lepidostrobi*, *Alethopteris lonchitidis*, and some *Sigillariæ.* There is also plenty of fruit there, *Cardiocarpon* and *Carpolithes*, as at the low beds of Trevorton. The last place where we had an opportunity to examine this vein, so rich in fine fossil plants, was at Great Kenawha River, 3 miles above Charleston, and there we found the roof-shales covered with *Alethopteris Serlii*, with some fine *Lepidodendra*, and *Lepidostrobi* in abundance. So we shall necessarily be forced to draw this conclusion, that this vein of coal, preserving well its character at such great distances, was formed at the same time, and under the same circumstances, both in the whole extent of the great Appalachian coal-field and in the anthracite basins.

Coming again to the highest vein of the great Appalachian coal, we find the same relation between the species of plants preserved in its roof-slates. We have not had any opportunity of seeing this bed cropping out in Pennsylvania. But at Pomroy, Ohio, the bed of coal there worked is generally acknowledged by geologists as one of the highest, if not the highest, of the basin. It contains an abundance of ferns, the same species as those found at Pottsville, especially *Neuropteris flexuosa*, Bt., which is there in such plenty as to cover entirely the roof-slate. And still higher, at Marietta, there is a red shale perfectly like the shale of the South Salem vein at Pottsville, on which we have seen *Pecopteris arborescens*, *Cyclopteris fimbriata*, Lesq., *Cyclopteris trichomanoides*, Bt., *Asterophyllites equisetiformis*, Bt., *Sphenophyllum Schlotheimii*, Lindl., *Annularia sphenophylloides*, Ung., all the species most commonly found in the highest beds of the anthracite coal of Pennsylvania. The only species peculiar to the place which we did not find at Pottsville, is our *Asplenites rubra*, Lesq., which, without the fructification, cannot be distinguished at all from *Pecopteris arborescens.*

This identity, so well established between the great Appalachian coal-field and the anthracite basins, by the vegetation of both the upper and the lowest veins, is of great importance; the more so as it is nearly the only affinity that it is possible to point out between these two basins. The difference in the nature of the combustible mineral is well enough established, and though it may be possible hypothetically to ascribe the transformation of bituminous coal into anthracite to the influence of heat, we have nevertheless some parts of the coal-basin where the matter does not evidence the slightest change, although apparently subjected to the same influences. Thus the lowest bed of coal at Portage Summit, elevated 2300 feet above tide-water, is still 1200 feet above the same bed of coal at Johnstown, without any appreciable diminution of the volatile matter.

As it is, the identity of the vegetation is the only reliable proof of the identity of both formations. But it is strong enough to eliminate any doubt, and so we are induced to look to some accidental circumstance for the cause of the difference. Perhaps it is especially to be ascribed to the remoteness of the small anthracite basins from the influence of the saline waters.

We would be the more inclined to admit this supposition, as from the base of the Ponent to the highest strata of the Anthracite coal, we could never detect any marine shells, when, on the contrary, these shells are very abundant in the true coal-basin, not only in the beds of limestone intermediate to the beds of coal, but in the shales of the coal itself.

It is not our task to speak of anything that does not directly belong to the vegetation of the coal; nevertheless we cannot omit to mention some geological facts which may help to the identification of the different beds of the great Appalachian coal-basin.

We have mentioned above, the thick Barren formation which separates the two stories of the coal. At the base of these Barren strata there has been formed in some localities a bed of grey shale, abundant in fossil plants. We have observed it at Portage Summit, where it contains especially *Pecopteris polymorphe*, Brongt.; and from the observation of the Rev. Mr Moore, in whose cabinet we have seen the beautiful *Neuropteris Moorii*, Lesq., it appears that this plant was found also at the same station, with many specimens of *Pecopteris polymorphe*. This shale is very often represented either by a thin bed of cannel-coal, or by a very black shale, covered with very small bivalve shells, together with impressions of ferns. We have observed it first at Portage Summit, then at Deer Creek, below Freeport; at Greensburg, three miles from the city, both E. and W.; at Beaver, in Pennsylvania; also at Nelsonville, in Ohio, and at Charlestown, in Virginia. The only bed of coal that we have had an opportunity of examining in Illinois—viz. nine miles E. of Terre Haute—is covered by these shales. A few feet above these shales, near the base of the Barren-measures, large trunks of trees, especially of the genus *Psaronius*, are found imbedded in strata of coarse sandstone. These trees are either transformed into sandstone or into limestone, and they have left only an impression (moulder) marked by a thin crust of coal, or entirely silicified, their internal structure being preserved. Their place in the vegetable kingdom is marked by the form of their vessels. Such trees are particularly abundant at Greensburg, Pennsylvania; at Athens, Ohio; and at Charlestown, in Virginia. We could probably point out another locality with a contemporaneous and identical formation—viz. the standing forest of Calamites and Sigillaria preserved in the sandstone above the bed of coal worked at Carbondale, in the anthracite basin. This may prove a new and interesting geological fact added to the one already mentioned, for the identification of both basins.

We have not made any extensive researches in the other coal-basins of America—viz. the basins of New Brunswick and New Scotia, Illinois, Wisconsin, and Iowa. The geological researches of others have already placed them in the same formation with the great Appalachian basin, and we have seen enough of the fossil plants collected in these different countries, to permit the conclusion that the vegetation of all is identical or contemporaneous. Among the fossil plants that we have received from New Scotia, there is not a single species which we did not find in the anthracite coal-basin at Pottsville; and all these plants, collected in a single place, have proved to us that the vein of coal from which they were taken is the upper vein of the basin. Mr Bunbury has enumerated a larger quantity of these fossil plants collected in New Scotia; yet in the whole number we find scarcely a single species unobserved in Pennsylvania. They are the following:—

Neuropteris cordate, with its variety *angustifolia*, is our *Neuropteris hirsuta*. *N. ingens?*—very doubtful, the specimen being incomplete, and the extremity of the leaflet broken off. *N. flexuosa; N. gigantea*, var., of which the author remarks that it is more an intermediate species between *N. gigantea* and *flexuosa*. We think it only a variety of *N. flexuosa*, as the true *N. gigantea* is scarcely an American species, though very often mentioned. All the specimens that we have received under this name belonged to *N. flexuosa*. *N. rarinervis*, Bunb.—a good species, very scarce in the anthracite basin; *Cyclopteris oblique*, Bt.; *Odontopteris Schlotheimii*, Bt. *Odontopteris subcuneata*, Bunb., has a great affinity with our *Neuropteris tenuinervis*, and may belong to the upper part of the frond of the same plant. *Dyctiopteris obliqua*, Bunb.; *Pcropteris emarginate*, Bt. *P. tæniopteroides*, Bunb., is nothing but a variety of *Alethopteris Serlii*, very often found in the lowest veins of coal at Minersville: the specimens received from New Scotia agree perfectly with ours. *P. nervosa*, Bt.; *P. plumosa*, Bt.; *P. abbreviata*, Bt.; *P. polymorpha*, Bt.; *P. cyathea*, *Sphenopteris obtusiloba*, Bt.; *S. artemisiæ folia*, Bt. *Sphenophyllum Schlotheimii*, Lesq.; *S. erosum*, Lesq.; *Asterophyllites foliosa*, Lesq.; *Bechera grandis*, Lesq.; *Pinnuaria capillacea*, and some *Lepidodendra*, *Sigillariæ*, and *Calamites*, identical with our species of Pennsylvania. It would be impossible to find a more striking identity between the vegetation of such distant countries.

The specimens received from Illinois and Indiana are still very few. But we have already mentioned that the only vein of coal that we have examined in this basin—viz. near Terre Haute, is the same in its fossil plants, and also in some other characters, as the first vein below the Barren-measures in the great Appalachian basin. There has not been collected around St Louis, and elsewhere in this basin, a single plant which does not belong to our flora.

The coal of Wisconsin and Iowa has been explored by Mr Dale Owen, who assigns it a position a little lower than that of the great Appalachian coal—viz. below the red shales of the Umbral series. It may stand so, but the plants that he has enumerated and delineated from species of *Lepidodendra*, would place the vein from which they have been taken exactly at the same level as our low bed above the Seral conglomerate. Both these strata of conglomerates and red shale may be wanting in the Wisconsin basin, and, though lying lower, the coal strata would then be, as I think they are, contemporaneous with ours.

From North Carolina we have received of late a fragment of the roof-shale of a bed of coal in a still lower position. This small fragment does not show any trace of vegetable remains, but only the shells of the Chemung (Vergent) group. It may belong to another period, but it is impossible to draw any conclusion from the small specimen alluded to.

The parallelism of the different basins, and even of the different strata, of coal in North America, being so fully ascertained, we have to look to a more general and not less interesting question—the comparison of the vegetation of the same period on both continents, America and Europe.

We could begin our comparison from the first formation where we find some remains of plants, viz., in the fucoids of the older Palæozoic strata; for we have there *Chondrites antiquus*, and many species of the same genus, identical with those found in Europe. But as these species have been described in the Report of the Survey of New York, and as we had not any good opportunity for examining the plants of the Silurian period, we may omit to mention them. We have found these *Chondrites* abundantly preserved in the Surgent group at Bloomsburg, and below the Vergent group at Portage Railroad.

The terrestrial flora of the older Palæozoic is either very limited or scarcely known. There are few localities where the Devonian strata have been entirely unfolded, and their shales, ordinarily coarse, are not fit for the preservation of the plants. This fossil middle Palæozoic flora, excluding the fucoides or marine plants, counts in Europe only about sixty species, distributed in eight genera. Though we are far from having found in America as many of these plants, we have been able to collect enough of them to ascertain the analogy, if not the identity, of the vegetation of the ancient formations, both in Europe and in America.

The *Calamites* are not scarce in the Ponent series of Pennsylvania, which corresponds to the Old Red sandstone. From the *Neuropterideæ*, Göppert, we have mentioned in the Chemung group, or upper Devonian system, our *Noeggerathia Boeksii*, which is the same plant as *Neuropteris Boeksiana* of Göppert, found in the old Palæozoic formation of Silesia. We have still three more Noeggerathia from the same formation in America, and of these *N. obliqua* is identical with the European species, and the two others are perhaps so; for their relation with some species already described is such, that the difference, if there is any, cannot be established without a comparison of the specimens of both countries. This predominance of the *Noeggerathiæ* in the beds of the Devonian age, both in Europe and in America, is itself a remarkable fact. They are the true ferns of the Devonian period, and they disappear entirely when we arrive at the lowest strata of the coal-formation. Pursuing our comparison, we find another point of affinity in the class of *Sphenopterideæ*. In the Devonian rocks of Europe there is only one species hitherto ascertained, viz. *Hymenophyllites Gersdorfii*, Göppert; and we have found in the Ponent rocks near Mauch Chunk a *Hymenophyllites*, which we refer with doubt to *Hymenophyllites furcatus*, Göppert; but which, by a comparison of good specimens, would probably prove to be the same species, the leaflets being often truncate, as *H. Gersdorfii*, the general appearance being alike. We did not see in the Devonian rocks of America any *Pecopteris*, but *Stigmaria Anabathra*, *Didymophyllum Brownianum*, and a *Pinorria*, which were probably found in the Devonian formation of Europe. Our *Stigmaria minuta*, which comes from the Ponent below Pottsville, is perhaps the same species as the undescribed *Sigillaria minutissima* of Göppert. Fruits, leaves, and stems of the undescribable *Lepidodendron* have been found as low as the formation Cadent upper black-slate, in the Juniata Valley near Huntingdon. These species are few in number, but their near affinity, or rather their identity, with those found in Europe, may remove any doubt as to the parallelism of these Devonian formations in both continents.

The same affinity of vegetation becomes much more evident when we come to the true coal. The general likeness in the flora of this period is so great that we could scarcely point out a difference, except perhaps in the *fimbriation* of some species of *Cyclopteris* and *Neuropteris*, and in our new genus *Scolopendrites*. But except this, in about two hundred and twenty species we have examined, there is not any form that has not a close relationship with the European species; and of these there are more than one hundred entirely identical species, and fifty more of which the differences which have necessitated a separation would perhaps prove accidental or invaluable, if better specimens had been procured. What is more striking in the analogy of these floras is, that the most common species in Europe are probably so in America, and this is also the case with the scarce ones. We will only mention a few examples of the most common plants of the coal-formation of Europe: we have *Calamites approximatus*, found in abundance at Carbondale; *Asterophyllites foliosa* and *Asterophyllites tuberculata*, two plants very common in the upper beds of the anthracite basin; *Sphenophyllum Schlotheimii*, which covers the roof-slates of the Salem Vein at Pottsville; *Neuropteris hirsuta*, L. (same as *Neuropteris cordati*, Bt.), *Neuropteris flexuosa*, with their corresponding *Cyclopteris; Neuropteris heterophylla;* very common plants in the American coal, like *Alethopteris conchitidis*, *A. nervosa; Pecopteris polymorpha*, *P. arborescens*, *P. arguto*, with some species of *Sigillaria* and of *Lepidodendron.* The most common fossil vegetation, as well in Europe as in our continent, is *Stigmaria fucoides*, which sometimes appears as if it had alone formed many veins of coal. We may as well mention here, that the remains are plentifully found in the coal itself, though it has been often denied that the coal of Europe preserved any impression of the plants which formed it.

Among the species which are scarce in both continents we find *Cyclopteris Germari*, of which we have obtained a single and small specimen; *Neuropteris tenuifolia*, *N. Willersii*, *Odontopteris Schlotheimii*, *Alethopteris urophylla*, *Callopteris Sullivanti*, a near relative to *Neuropteris conferta* of Göppert, *Pecopteris ovata*, *P.*

abbreviata, &c. These affinities of the vegetation of the coal period serve to give us positive proof that the Palæozoic coal-basins of Europe and of America were formed exactly at the same time; but we do not think that it would be right to draw the conclusion that at this time the vegetation of both continents was identical.* On the contrary, we find, by comparison of the flora of the coal, that, with all its points of likeness, it had as many dissimilar ones as the existing flora has now, and that the distribution of the plants presented about the same proportion and disproportion as in our time.

But before looking at this question, it is necessary to understand what points of reliance we shall find for the security of our comparison, and where we shall find them.

It has many times been questioned if the fossil plants found in the Coal-measures would give us any good general view of the vegetation of the Palæozoic era. This is easy to answer. Either the whole surface of the emerged country was low, marshy, covered with the plants which formed the coal, and the remains of these plants found imbedded in the shales are a pretty accurate representation of the vegetation of the coal; or there were dry and high lands around the marshes, and then the petrified plants found in the Coal-measures would not give us a better view of the general vegetation than the plants of the peat-bogs would give now of the vegetation of the surrounding hills. It has been a mistake of many authors to look at the vegetation of the coal, and draw conclusions from it without a clear understanding of its nature. It is, I think, unnecessary to recall here either the proofs of the formation of the coal by the heaping of vegetable matter, or the growing of the plants of the coal at the place where their remains are now found; there is already evidence enough on that question. But we require to remember a few of the laws of nature, to give us a better view of the subject.

The woody matter of the plants is produced only by the absorption and elaboration of the carbon of the atmosphere. The more the atmosphere is saturated with humidity, the more carbonic acid is absorbed by the plants. The more of light and air there is around the plant, the more this carbonic acid is elaborated to produce the largest proportion of woody matter. This fact, which is directly proved by chemical experiments, is elucidated by nature everywhere around us. The plants entirely covered with water have a very small amount of woody matter in their tissue. And so we can assert that the true marine plants, or the *Fucoides*, have never contributed a large share, if they have at all, in the formation of coal. On the other hand, plants living in a very dry atmosphere have ordinarily a large supply of sap and watery matter, like the Cactaceæ and the fleshy Euphorbiaceæ of sterile regions; but they contain a very small proportion of woody matter; and so we can eliminate at once this supposition that some plants of the coal, the *Sigillariæ*, and the *Stigmariæ* especially, might belong to the family of the Cactaceæ or of the Euphorbiaceæ, as it has been asserted by some authors.

Going farther into this subject, we find that the plants especially composed of woody matter have need of another proceeding of nature to preserve this matter from decay, and to transform it into coal. This is performed by humidity, or by water. Every particle of dead woody matter directly exposed to the air, is by-and-by entirely consumed by the action of the oxygen; it is rotted, as we call it. But when the action of oxygen is tempered by the presence of a large proportion of water, the procedure is slow, and then the decay of wood is exactly like its transformation into charcoal; viz., a true slow burning, and a carbonisation. It is then necessary to conceive the formation of the coal as the result of half-aerial, half-watery vegetation, exactly that of our present peat-bogs. This is the simplest and the most natural way to explain the formation of the coal; and the affinity is so evident that it is scarcely possible to understand how it has been so long overlooked. Naturalists have, one after another, habituated their minds to construct systems and hypotheses which the simplest observations destroy, and have forgotten to look at the work of nature, which is always the same, immutable in its laws as in everything that is great and eternal.

If this were the place, we would like to explain at length our views about this analogy of formations now pointed out, and compare minutely the old formation of the coal with the new ones, or with the peat-bogs, which are nothing but beds of coal not entirely ripe or burned out. We would have to mention some very interesting and striking analogies, such as the presence of bitumen in both formations. It has always been asserted that bitumen could not proceed from plants, and it is now everywhere obtained by the distillation of peat. We would show the identity of the geographical distribution of both formations, though it has been long asserted that the peat formation belongs to a cold climate, and the coal to a warm one; also the affinity of form in their plants, the leaves of which are nearly all either grass-like or small, pointed, and like needles, both forms particularly adapted, it seems, to the absorption of the vapours, and the transformation of carbonic acid in woody matter, and show the large amount of wood in the plants of our peat-bogs, even in the mosses (sphagna), which, though very fragile, soft, and thread-like plants, have a larger proportion of woody matter than the hardest and largest of trees.† This analogy of formation being established, we do not see any reason to theorise about the general flora of the period of the coal-formation. It is useless to experiment on a large amount of plants of our time—especially plants living in conditions that render their presence impossible in the coal-formation, to draw hereafter any conclusions about the number of species of plants living in former ages. It has been already observed by Mr Bunbury, that the careful observations of Mr Lindley on the length of time which some plants may stand immersed in water without losing their form, cannot help in any way to our acquaintance with the flora of the coal. We will here only mention that if the same experiments had been performed only on the plants of our peat-bogs, the conclusions would have been more rational. We take an example from the family of the mosses. Mr Lindley has experimented on six species, viz. *Hypnum striatum*, *H. sericeum*, *Dicranum purpureum*, *D. scoparium*, *Bryum undulatum*, *Polytrichum commune.* The natural function of all these species of mosses is to cover the base of the trees, or their decayed parts, either to protect the roots, or to form the black earth or humus by their decay. So they are quickly-decaying species. The true mosses of the peat-bogs are the *Sphagnum*, all the species; some *Hypna*, especially *Hypnum trifarium*, *H. fluitans*, *H. scorpioides, H. niteus;* some species of *Dicranum*, as *Dicranum Schraderi*, *D. palustre*, &c.; and certainly if these mosses, with the bog-rushes (Junci) and the sedges (Carices) of the peat, were subjected to the same experiments, the result would prove very different. We have found in the peat-bogs of Switzerland some beds of *Hypnum trifarium* under 10 feet of entirely black and decomposed peat, which were so well preserved that the species could be perfectly and easily identified. We have also received specimens of *Hypnum fluitans* found in Berlin, under 50 feet of sand and water, which are in as good condition as if they had been preserved in a collection of dry plants. To elucidate this point, and to show what is the vegetation of the peat-bogs of Europe, and what relation this vegetation may have with that of the coal-formation, we will translate a passage from the work already quoted on the formation of the peat-bogs, (page 131, quarto edition) :—

---

* As many authors have done, *vide* Bunbury, &c. Some have gone so far as to suppose that at the coal epoch the Atlantic did not separate both continents, and that the coal-basin of England may be a continuation of that of Nova Scotia.

† All these facts have been stated at length in *Recherches sur les Dépôts tourbeux en général*, by the author of this report.

"The analogy is not the less remarkable, if we consider the classes of plants which have formed both combustible substances. Mr A. Brongniart found in the old coal—(*a*) About ten species of fucoides. This family of plants is the same as the *Fucaciæ* of our time, which are marine plants found in great abundance in the peat-bogs of the north.[*] (*b*) About nineteen species of the Horse-tail family, or *Equisetaceæ*. The species of the same class were at one time very abundant in the ditches of the peat-bogs. The family of the *Characeæ*, a near relative to the former, is most abundantly found in the standing water of the marshes. (*c*) More than one hundred and twenty species of ferns, and nearly seventy species of *lycopodiaceæ*, cryptogamic vascular plants, which might be referred to on account of a likeness in tissue and growth to our cryptogamic cellular plants. Our peat-bogs have also more than seventy species of mosses, five or six species of lycopodiaceæ, and as many species of ferns. (*d*) Eighteen or twenty species of palm-trees, reeds, and phanerogamous monocotyledonous plants; and our peat-bogs are now essentially a compound of such plants, sedges, grasses, and reeds, &c. The trees that are now living on our peat-bogs—viz. the pines, the birches, &c.—probably take the place of the large series of palm and fern-trees of the marshes of the Old World. And as is the case in the coal-beds, where no well-characterised remains of dycotyledonous plants are found, so in the peat it is impossible to find any trace of the few dycotyledonous plants living on the marshes, except perhaps some trunks of trees."

The above was written ten years ago; since then the palæontology of the plants has made very great progress, and a great many new species have been discovered. Nevertheless, this analogy in the vegetation of both formations, viz. the coal and the peat, has become more and more evident. It is a peculiar flora, evidently adapted to a peculiar purpose, which in its study ought to be looked at in its entireness, and without any relation to the vegetation of any other part of the country.

Such being the case, our task of comparison between both the coal-floras of Europe and America becomes an easy one, and we shall easily show what is the value of the conclusion of a celebrated English geologist : "Whereas, it appears that of all the fossil plants which have hitherto been procured from the carboniferous deposits of these regions (British America), a great majority are undistinguishable from British species, it is well known that the recent vegetation of Pennsylvania, Maryland, and Ohio, is altogether of a different type from that of Europe." †

In the peat-bogs of North America, ordinarily named cedar swamps, there are first about twenty species of mosses of which the growth directly contributes to the formation of the peat. They are—

1. *Sphagnum cymbifolium*, Ehrh.; 2. *S. squarrosum*, W. and M.; 3. *S. recurvum*, Beaur.; 4. *S. acutifolium*, Ehrh.; 5. *S. cuspidatum*, Ehrh.; 6. *S. compactum*, Bred.; 7. *S. contortum*, Schultz; 8. *Dicranum Schraderi*, W. and M.; 9. *D. palustre*, Br. and Schp.; 10. *Meesia longiseta*, Hedw.; 11. *M. tristicha*, Br. and Schp.; * *Aulacomnium palustre*, Hedw.; 12. *Hypnum trifarium*, W. and M.; 13. *H. stramineum*, Dicks; **H. niteus*, Hedw.; 14. *H. curdifolium*, Hedw.; 15. *H. stellatum*, S.; 16. *H. fluitans*, S.; 17. *H. aduncum*, S.; 18. *H. scorpioides*, S.; 19. *H. paludosum*, Fult.

Of these species the last one only is peculiar as an American plant, all the others, without exception, have the same plan, the same destination, and are found in the same abundance in the peat-bogs of Europe. There are many other species of mosses which are growing only on the peat, but which do not claim a large share in the combustible matter, viz. :—

1. *Splachnum ampullaceum*, S.; 2. *Polytrichum gracile*, Meux; 3. *Dicranum cerviculatum*, Hedw.; 4. *Hypnum cuspidatum*, S.; 5. *H. phatense*, Koch; 6. *H. filicinum*, S.

All species found also on both continents in the same places.

---

[*] Since writing this opinion, we have had an opportunity of exploring the peat-bogs of the north of Europe, in Sweden, Denmark, and Holland, and have not been able to find any trace of a true bed of peat formed by marine plants or fucus. And since that time, also, both the explorations of other authors and our own have clearly proved that there is not any true *fucoid* plant in the coal, and that all the impressions which were supposed to belong to such marine plants represent either the roots of some vegetable, or some new species far removed from the fucoides.

† Mr Banbury.

Coming to the ferns in ascending the grades of the vegetable kingdom, we find in the marshes of America—

1. *Woodwardia Virginica*, Willd.; * 2. *Dryopteris thelypteris*, Adam; 3. *D. Noreboracensis*, Adam; * 4. *D. cristata*, Adam; 5. *Osmunda spectabilis*, Willd.; 6. *O. Claytoniana*, S.; 7. *O. Cinnamomea*, S.; * 8. *Ophioglossum vulgatum*, S.; * 9. *Lycopodium inundatum*, S.; *10. *L. clavatum*, S.

Seven of these species could scarcely be distinguished from their European relatives, if they were found in a fossil state, so great is their likeness, and five of them are entirely identical with these.*

The sedges and grasses are distributed also in the same proportion. We will enumerate only the American species, with a mark * for those which are found on both continents.

1. *Narthecium Americanum*, Re.—scarcely distinguishable from the European *N. ossifraga*, Lamark; * 2. *Juncus effusus*, L.; * 3. *J. maritimus*, L.; * 4. *J. acuminatus*, Michx.; 5. *J. molitaris*, Bigel.; * 6. *J. stygius*, L.; * 7. *J. bufonius*, L.; 8. *Xiris bulbosa*, Kunth.—a truly American species, without analogues in Europe; * 9. *Eleocharis palustris*, R. Brown; * 11. *Scirpus cæspitosus*, L.; * 12. *S. pungens*, Vahl.; 13. *S. Torreyi*, Oln.—scarcely distinguishable from *S. mucronatus* of Europe; *14. *S. lacustris*, L.; *15. *Eriophorum alpinum*, L.; *16. *E. vaginatum*, L.; * 17. *E. gracile*, Koch; *18. *Rhynchospora alba*, Vahl.; 19. *R. capillacea*, Torr.; 20. *Cladium mariscoides*, Torr.—very near *C. mariscus* of Europe; * 21. *Carex dioica*, L.; * 22. *C. pauciflora*, Ligth.; 23. *C. polytrichoides*, Muhl.; * 24. *C. terctiusculo*, Good.; * 25. *C. paniculata*, L.; * 26. *C. chordorhixa*, Ehrh.; * 27. *C. gracilis*, Ehrh.; 28. *C. trisperma*, Der.; * 29. *C. stellulata*, Good.; * 30. *C. limosa*, S., and its variety, *C. irrigua*, Smith; * 31. *C. Buxbaumi*, Wahl.; * 32. *C. filiformis*, L.; 33. *C. lanuginosa*, Michx., scarcely distinguishable from the former; 34. *C. folliculata*, L.; 35. *Leersia oryxoides*, Swarth; 36. *L. Virginica*, Willd.; 37. *Glyceria Canadensis*, Trin.; 38. *G. nervata*, Trin.; * 39. *G. aquatica*, Smith; * 40. *G. fluitans*, R. Brown; * 41. *Pragmites communis*, Trin.

To the flora we would have to add the *Typhaceæ*, **Typha latifolia* and **T. angustifolia*, some *Sparganium* (burr reeds) and *Potamogeton* (pond weed), species identical to both continents; and for the trees: **Abies alba*, Michx.; *Larix Americana*, Michx., so near *L. Europea* that it only differs by slender and shorter leaves; *Taxodium distichum* growing in the southern swamps; and a few willows and other dycotyledonous plants, of which the remains are not preserved, or at least never recognisable, as the *Utricularia*, of which the species are also identical in Europe and in America; *Nymphæa adorata*, Act., very like *Nymphæa alba* of Europe; **Nuphar lutea*, Smith; *Sarracenia purpurea*, S., truly American; **Viola palustris*, S.; **Drosere rotundifolia*, S.; **D. longifolia*, S.; **Parnassia palustres*, S.; *Janguisorba Canadensis*, S.; **Comarum palustre*, S.; **Vaccinium oxicoccos*, S.; *V. macrocarpon*, Act., distinguishable from the former only by the fruit; **Chiogenes hispidula*, Torr. Sq.; **Andromeda polifolia*, S.; **Veronica sartellata*, S.; **Scutellaria galericulata*, S.; **Calla palustris*, S.; **Scheuchycria palustris*, S. There is only a very great difference in the family of the Orchideæ, of which the American peat-bogs have a few very beautiful species entirely different from the European. But this family is the most polymorphous in its distribution, and cannot by itself be taken for a general comparison of a flora. The trees also have some more species which cannot be compared; but a great many of them, the birches and the alders, are nearly alike. How, then, is it possible to assert that two floras of about 100 species, which have more than seventy entirely identical forms, and ten or fifteen more very nearly alike, are *altogether of a different type?* We must necessarily adopt a contrary conclusion. The type of the flora of the peat-bogs is everywhere the same; and if we had time to pursue our comparison, we would prove it easily, as well from our explorations in the great bogs of Southern Virginia, as from the observations of travellers in the Australian hemisphere.

The same identity of type is altogether evident in both the Palæozoic floras of America and of Europe. We remark in them the same analogy and the same difference,—a great many species entirely identical, many so related that their differences are pointed out only with great difficulty, and a few entirely different. This will evidently appear in the examination of our described species; and we are necessarily led to conclude—

1. That at the time of the coal-formation the floras of both continents had the same analogy and the same difference that they have now.
2. That both continents were, as they are now, separated and distinct.
3. That both were *respectively* under the same atmospherical influences.
4. That nothing can authorise us to admit these atmospherical influences as very different from what they are now.

This last assertion, so far different from the conclusions of other celebrated geologists, necessarily needs some explanations.

It has been long asserted, as we have already said, that the peat-bog formation belongs particularly to cold climates, and that the preservation of the woody matter is essentially due to low temperature. Our researches in Europe on this subject have already proved that this is not the case, and that the area of the peat-bogs occupies exactly the same latitudes as that of the oldest coal-formations.† And since we have been enabled to pursue the same exploration in America, we have found on this continent exactly the same distribution. For in this country the peat-bogs are found from far above the northern shores of Lake Superior, as high as 60° of latitude, to the great Dismal Swamp in South Virginia 35°,—exactly in the same latitudes as are occupied by the great coal-basins of America. We have made on this subject very long researches, and we have never obtained specimens of a true coal in the Northern hemisphere from Southern latitudes. The beds of coal mentioned in Texas and the coal of Brazil, are only beds of lignite; a formation entirely different from that of the coal, independent of any peculiar formation, and so without any geological interest.

---

* Moreover, the species of the ferns and Sycopodes of America have in general the greatest likeness to those of Europe.

† Vide *Recherches sur les Marais tourbeux en général.*

But those immense trunks of trees, perhaps of fern trees, to which we find an affinity only in the tropical regions, how is it possible to account for their vegetation in our latitude, if we do not admit of a great change of temperature? 1. In the peat-bogs of Northern countries, of Denmark, Sweden, and also in Switzerland, we find sometimes, heaped in very thick strata, much larger trunks of trees than those which have been found in the coal. The following is a description given, in 1846, of a peat-bog which we visited near Waldsmarslund, 30 miles above Copenhagen:*—"These deposits of wood are a true forest heaped upon another, and buried in the peat, which in these marshes (of Denmark) are found everywhere with alternating beds of the same species of trees. At the bottom, upon a bed of peat from 4 to 6 feet thick, are *pine-trees*, lying flat, nearly always in the same direction as the inclination of the basin, viz. the roots against the borders. These pine-trees are ordinarily from 6 to 10 inches in diameter; they have their slightest branches preserved, and are imbedded in a mass of their own leaves, cones, mushrooms, &c., of which the form is not at all altered. Upon these pines is a bed of black peat from 5 to 6 feet thick, overlaid by a forest of prostrated white birches. Upon the birches there is again 6 feet of less-decomposed peat, covered with enormous trunks of oaks, which have no less than 3 feet of diameter, and of which the wood is so well preserved that it is sawed on the place, and used for building-material. The matter or peat in which these trees are buried does not preserve any trace of the leaves of these oaks, but only some acorns. It is evident, nevertheless, that they have grown on the place where they are found, being preserved in their integrity with their smallest branches and their bark. These trees are covered by from 6 to 8 feet of peat, in which, or upon which, is found sometimes a fourth forest of trees, and this time, of beech-trees, the same trees that now form the forest around.† The size of the trunks buried in the peat-bogs is, as is easily seen from the above description, in favour of our present formations. In the Dismal Swamp in Virginia, we have seen in the peat trunks of Magnolia measuring more than 100 feet, without great diminution in their diameter. 2. The trees of the coal, which, like Lepidodendron, Sigillaria, and Stigmaria, are ordinarily ascribed to a genus of plants like the ferns, and so to fern-trees, were not true ferns, but a peculiar species of plants, of which we have no living representatives, and of which the nearest relatives are the Lycopodiaceæ, a genus of plants of which the largest species known are living in the beat-bogs and the forests of our Northern hemisphere. The true fern-trees (Caulopteris) are very scarce in the coal; their diameter does not appear to be large; and if this class of vegetables does truly belong now to the tropical regions, it is well to remember that they are especially found in a very wet atmosphere, either on the small islands or on the highest mountains of Java, either on large marshes or on the borders of shallow and muddy lakes, where the temperature is certainly not the cause of their presence. 3. It is generally known how great is the influence of the dryness of the atmosphere on its temperature. We have only to compare the climate of the evergreen Ireland with that of the central part of Europe under the same latitude, to ascertain what difference this atmospheric agent makes on the vegetation. The best proof we could afford of it is the presence of large trunks of oak-trees at the bottom of the peat-bogs of Switzerland, in valleys many hundred feet above the oak region, and consequently where now there are only some forests of pines. Since the clearing of these valleys, and the draining of the land, the climate has perhaps not become colder, generally speaking, but the extremities of temperature are more distant; colder in the winter, with a stronger heat in the summer. Every one knows, that it is precisely the degree of this difference which regulates the vegetation of a country."

It is, then, sufficient to give us the reason of the difference in the type of vegetation between the coal period and our own, to admit that the continents were less extended, and only low islands entirely covered with marshes.

But all the physical phenomena of our time were then in activity. We find upon the red shales of the Umbral series the evident marks of drops of rain and of hail; the cracks also caused by dryness under the action of the sun upon the mud. We have in the small horizontal layers of the coal, of which the thickness scarcely attains the twelfth part of an inch, the proof of an annual decay, and of an annual heaping of the plants exactly as we find it in the peat. What more is wanted to authorise the conclusion, that our world has not changed its course since the formation of the coal—that the hypotheses of a displacement of the axis of the earth, of great and sudden commotion, of extraordinary temperature, of nebulous atmosphere, and the like, have not any basis on known facts? Our human race is young, but the world lived long before it, and has not changed its revolutions expressly for our purpose. Truly nature has prepared our home. It has heaped, for the future welfare of our race, those inexhaustible beds of combustibles that afford us so much comfort; but it has done this without any miracle, without any of those sudden transitions which we are so prone to discover for the satisfaction of our own pride.

As it is, nevertheless, this coal-formation is an admirable one; and we can look to it only with wonder and with faith to an overruling and provident Director. For this heaping of combustible matter was by itself nothing

---

[*] Vide *Explorations dans le Nord de l'Europe, pour l'étude des Dépôts de Combustibles mineraux.* Leo Lesquereux; Neuchatel, 1846; p. 68.

[†] It is well to remember that in Europe the forests have not so many species of trees as in America, and are ordinarily composed of a single species, or seldom of two or three.

but a useless proceeding. The bed to put it in was to be prepared, a long time in advance, by a thick layer of clay, to prevent the egress and the dispersion of the bitumen after its separation from the woody matter. It required also an impermeable covering to prevent too strong an action of the oxygen, and the mingling of sand and other strange matters, which would have entirely changed its combustible property. This, as well as the formation of iron, which is also ordinarily in progress with the formation of the peat-bogs, has been obtained by the simplest laws and the slow progress of nature. The places where these formations were progressing have been subjected to some slow and periodical upheavals and depressions, which are remarked even at our time on the sea-shores of some countries—of Holland and of Sweden. By these slow depressions, the water, saturated with iron, has first covered the beds of combustible matter, and deposited these particles for the formation of the shales; a greater depression has given access to a strong current of water, which has heaped the sand upon the shales, and so, by a repetition of the movement, the woody matter has been formed, then enclosed, then heaped in different beds one upon another; preserved from decomposition, or from the influence of the atmosphere; transformed into coal by the slow disengagement of the gas, and the high temperature of the earth.*

To close the few observations that we are entitled to make here, it is necessary to give an explanation of some local phenomena, of which the causes are still in discussion.

The appearance of the trunks preserved in the coal-shales and in the sandstone is very different. In the sandstone the trees have left an impression of their whole external surface in its primitive form; but they have not left anything else except this impression, and the whole primitive substance has been destroyed, or transformed either into silex or into limestone. In the shales, on the contrary, and immediately above the coal, the woody matter of the trees is preserved, transformed into coal; but the primitive form is entirely changed, the trees having been flattened, and having left only the impression of this flattened surface, as if the bark alone had been preserved and pressed together. We have seen that the wood exposed to the action of the oxygen of the air is slowly but entirely rotted and destroyed. The air, having access through the particles of sand, produces by-and-by this result on all the wood buried in it. Nevertheless the sand around the wood is by-and-by hardened, and the stony substances — either sand, or carbonate of lime, or silex — penetrate all the destroyed part of the wood in such a manner, that, following the circumstance, the vegetable is mouldered into some of these substances. At Carbondale and Greensburg the trees in the sandstone are transformed into sandstone, and their tissues entirely destroyed. At Gallipolis and Athens they are silicified or transformed into limestone, and the silex only has preserved the form of the vessels of the wood. We cannot give any explanation of the petrification of organic substances; it is still an unexplained mystery. Who could tell how it happens that, in the same bed of sandstone, and exactly in contact with each other, we find, as at Gallipolis, two trees, one of which is transformed into limestone, the other crystallised, or entirely silicified? We have seen also that when the action of the oxygen of the atmosphere is nearly prevented, the woody matter is slowly burned into coal. This proceeding does not come to its end without a great many changes. One of these modifications is the transformation of the woody matter into a soft black mud, most easily flattened by the compression of the superior strata. Sometimes, when water is abundant, this black mud becomes nearly fluid; and as the bark of the trees is preserved by its *tannin*, it is not only flattened, but folded into a very thin space. We have seen some beautiful illustrations of these changes in Germany and Denmark. Near Leipsic there is a bed of lignite, formed of large trunks heaped about 15 feet thick. The matter is entirely soft, and all the trunks flattened, measuring in one direction scarcely half the diameter that they have crosswise. It is also entirely black, and yields an excellent fuel. It is extracted with shovels, like the peat, after its surface has been laid bare, from 20 feet of sand and gravel lying upon it. In Denmark, about 20 miles below Copenhagen, near the sea-shore, there is an extensive plain covered with the finest grass, and affording excellent pasture to large herds of cattle. By digging there they find, under 1 foot of humus, a bed of *peat* (?), entirely composed of bark of birches. This bark is heaped 6 feet thick, and closely packed and flattened. It is first dug or cut out, and dried in long rollers, entirely void of earthy matter. The woody matter, nearly fluid, or transformed into a very soft yellow mud, is at the bottom of these beds, and is then taken out of the excavations with buckets, then put on layers of straw, through which the water percolates; and when thickened, it is beaten hard, dried, and burnt like coal.

It happens sometimes, as we have seen at Carbondale, that standing petrified trees are found in the sandstone of the Coal-measures. This accident is easily accounted for, as soon as we admit it only in the sandstone or in the shales of the coal. For if the sand carried by water has been quickly deposited in great thickness, all the trees growing on the marshes have been imbedded in it, and preserved in a standing position. But when this occurrence is reported, of trees having *their roots below a bed of coal, crossing the coal, and penetrating the sandstone above*, we can but pronounce this fact an impossibility, for it is against the laws of nature. It requires very little acquaintance with botanical physiology to understand that trees can never grow when their roots are covered with standing water, or with a stratum of matter impenetrable to the atmosphere. Hence it happens that all the trees—pines, firs, cedars, willows, &c.—living on a marsh, or on a cedar swamp, have their roots horizontally expanded, and as near the surface as possible. Hence also the necessity for the coal trees being supported by such creeping roots as the *Stigmariæ*. When a tree is covered by a bed of decayed woody matter and by water, it soon dies, and rots immediately above the water, where the humidity and the oxygen of the atmosphere have free access. From this cause, all the trees decaying or dead on the peat-bogs are very soon prostrated.

---

* Liebig has given the history of the chemical process of the formation of coal in his *Chemical Physiology*.

It is also, we think, a very false idea of the growth of the vegetable matter of the coal-beds, to believe that a tree, even in the most favourable conditions, could stand as long a time as it was needed for the formation of even a thin bed of coal. It is not a century, but thousands of years, that have been required to heap a bed of coal of a few feet of thickness. In the bituminous coal of Ohio the annual growth of the coal is well marked by the thin layers, which are about 1-12th of an inch in thickness: so, such beds of coal as the Pittsburg Seam would have required for their formation a period of time of about 1500 years.

A peculiar phenomenon has been observed in England, and may also attract the observation of the naturalists of America. Sometimes, in the internal part of the petrified trees of the Coal-measures, one finds an abundance of fruits and leaves of the same species—viz. *Lepidostrobi*—in the trunks of *Lepidodendra*. We have had a striking explanation of this in our last visit to the Dismal Swamp, on the shores of Drummond Lake. We went there to compare the formation of the peat in its Southern latitude, and found it entirely identical with the same formation in the cedar swamps of the North. The only difference consists in other species of sphagna, and other species of trees, and in the undergrowth of canes, which form there an impenetrable thicket. In the middle of this marsh there has been a depression filled with water, and which has formed Drummond Lake. Its depth is about 15 feet only, and its bottom is covered with prostrated trees—a fact that proves that it has been formed by depression of a surface primitively extending over a sheet of water, and covering it. This formation is of very frequent occurrence in the North of Europe and of America. Around the lake grows the bald cypress (*Taxodium distichum*), and sometimes the trees are half-covered with water, and decaying in such a manner that their standing trunks are entirely hollow. The fruits and leaves of the trees around, falling into the water of the lake, and drifted here and there, are arrested by the hollows of these trees, and fill them almost entirely. If these trees were imbedded in sand, and by-and-by petrified, they would exhibit exactly a repetition of the phenomenon alluded to, of fruits and leaves found in the trunks of their own trees. There are many other similar phenomena of the Coal-measures, which would find an easy explanation from detailed description of the formation of our actual peat-bogs. But we have already exceeded the limits assigned to us in this paper, and shall refer for further details to the books mentioned above.*

LEO LESQUEREUX.

DESCRIPTION OF THE FOSSIL PLANTS FOUND IN THE ANTHRACITIC AND BITUMINOUS COAL-MEASURES OF PENNSYLVANIA.

BY LEO LESQUEREUX.

AMONG the plants here described, only a very small number have been found beyond the limits of Pennsylvania. They are mentioned for the peculiar interest they present, either in their form, or in their geological position. The greater number of these fossils were collected by ourselves. A few of them, nevertheless, were studied in the rich and beautiful cabinets of Mr Clarkson at Carbondale, and the Rev. W. Moore of Greensburg. Both these gentlemen gave us, with the greatest kindness, the liberty of copying and describing all the new plants in their possession. With great pleasure we take this opportunity of returning them our thanks. Though there is much to say upon the classification of fossil plants, we are not at liberty, in such a work as this, to enter into long scientific discussions upon the value of the genera as they are now established. We have followed the classification adopted by the best European authors, especially by Brongniart. Nevertheless, as no general description of these fossil plants of America has appeared till now, and as many of our naturalists may look to this enumeration for a direction of their researches, we have thought it necessary to append some general remarks as often as our views do not correspond with the opinions of the high authorities mentioned.

FIRST CLASS.—*Fungineæ*.

Except *Polyporites Bowmanni*, Lindl., no discernible trace of any kind of mushroom has been found in the coal. Very often the stems of the ferns are covered with elevated points of different size, which closely resemble the small *Thyponileæ* of our time, especially the *Spheriæ*. But it is not possible to ascertain if such marks left on the stems have anything organic in their nature, or are only accidental. That they are very often produced by accident, is proved by their presence on different plants, and on different parts of the vegetables—even on some slates, where there is not any trace of vegetable impressions. The points are especially observable in the coal-basin of Trevorton, where coal-slates—even the slates which do not appear to have contained any bituminous matter—are full of *vesicles*, from the size of a needle's head to the size of a pea. They are filled with a brown powder, which to the naked eye has exactly the same appearance as the spores of the *Spheriæ*, but which, when looked at with a strong microscope, does not present any trace of organisation. It is only a very inflammable bituminous matter. The appearance of those small cells may show the operation of transformation of coal to anthracite. In the half-anthracite coal, the ebullition did not proceed far enough to accomplish the ejection of the gas. A great part of the vesicles were only formed, but did not burst before the cooling of the matter; hence, perhaps, these cells.

As for *Polyporites Bowmanni*, we have found it exactly as described by Lindley, and cannot but admit it to be a true fungus. It is easily discernible by its concentric zones or lines, and its surface thickly perforated with small points. It is, however, very different from *Carpolithes umbonatus*, Sternb., to which M. Brongniart has compared it.

---

* Though I do not assent to some of the theoretical views maintained in this ingenious Essay, nor accept some of the statements, as that the Palæozoic coal-formation does not extend beyond the latitudes embracing the existing peat-bogs, I must thank the author for the amount of accurate and curious information which it contains. H. D. ROGERS.

Second Class.—*Algæ.*

After a careful examination of all the specimens reported to belong to this class of plants, we do not find a single sea-weed in the Coal-measures of Pennsylvania. Many species of *Algæ* are found below the coal, especially, in the Clinton group, where they are accompanied by marine shells—*Brachiopodes*, *Crinoides*, and some *Acephales*—but in higher formations they by-and-by disappear altogether, and all the so-called *Fucoides* of the Ponent and of the Vespertine formations are either roots or stems of other plants. Certainly many of these roots closely resemble those of *Fucoides.* The branches are short, obtuse, very numerous, without order, either simple or branching again, without any perceptible diminution in their thickness, from one end to the other. But we find exactly the same appearance at present in many roots dipping in water, where they extend and branch in every direction, in shape sometimes like a thick bunch of twine. The best proof of our opinion being right is, that we have found many of the so-called *Fucoides* attached to the stem. We have made drawings of the most interesting of them (see *Pinnularia*, Plate XVII.), only to show how carefully we have to proceed in the study of these fossil remains.

The same may be said about some thread-like, hard, shining vegetable remains found in great abundance on the slates of the coal around Pottsville, and mentioned also as occurring in the coal-basins of England and France. They were supposed to belong to the *Conferves*, or fresh-water *Fucoides;* but besides their tubular form, there is nothing to sustain this supposition. They vary in thickness from a hair's-breadth to one sixteenth of an inch in diameter, and appear ordinarily piled one upon another, without any general order. As they are never flattened, and do not present any trace of articulation or of ramification, it is not possible to compare them with the *Conferves*, these being very weak and brittle plants, of which there could not exist any trace in the vicinity of the coal where the materials were for a long time exposed to decomposition. They are found sometimes even in the coal itself. They are without doubt the true roots or fibrous appendages attached either to the subterraneous or creeping stems of the ferns, and generally named Rootstocks. Their description belongs to the genus *Pinnularia* (which see). *Fucoides dentatus* and *Fucoides serra* (Brongt., *Hist. des Veg. Foss.*, p. 70, t. 6, fig. 9), found in the older Palæozoic limestone of Canada, evidently belong to the genus *Graptolites*, and so are out of the vegetable kingdom. We have found a single specimen of these fossils in the greenish sandstone of the *Ponent* rocks near Trevorton. But they have been found in great abundance in the State of New York, and have been closely described by Professor Hall in his Geological Report.

The only true *Fucoides* that we have to describe belong to the following genus:—

I. Chondrites, Sternb.—Frond cartilaginous, thread-form, dichotomous; branches cylindrical, but flattened in the impressions.

1. *Chondrites antiquus*, Sternb.; *Buthotrephis? flexuosa*, Hall (*Paleont. of New York*).—Frond bipinnately forking; branches and branchlets diverging, inflated at the forks, branchlets linear, obtuse. Very abundant in the Surgent group at Bloomsburg, and at the base of the Alleghany Mountain, below Portage Summit.

2. *Chondrites Fargionis*, Sternb., Vers. II., p. 25.—Frond bipinnately branching; branches elongated, linear, obtuse, entire or scarcely branching. Var. α, *fastigiatus;* frond straight, erect, irregularly pinnately divided; branches linear, simple, or branching. Var. β, *divaricatus;* frond irregularly pinnate; branches diverging, unequal. Var. γ, *confertus;* frond erect, densely pinnately branching; branches filiform, unequal.—Brongt., *Hist. des Veg. Foss.*, i. p. 56. Same locality as the first.

This plant, as described by Sternberg and Brongniart, was found at different places in the cretaceous formations of Europe. Such a difference in the stations would lead us to suppose that our American plant is a different one. Nevertheless, as we find not only the typical form, but also the varieties as they are figured and described, we are not at liberty to change the name, and to admit it as a new plant. We have figured our specimens to give opportunity for a close comparison (Plate XVII., figs. 13, 14, 15, 16, 17).

II. Fucoides, Harlan.—We cannot point out any characteristic marks to describe this genus. It has been preserved for the classification of some organic remains of which the indefinite forms do not clearly indicate an affinity with any known genus of sea-weeds. The two American species generally admitted in this genus have more the general appearance of some corals than that of *Fucoides.* We had an opportunity of studying them in great number, and in as good a state of preservation as it is possible to find them. They are very numerous in the sandstone of the Levant white sandstone series of the Juniata River, below Lewistown and above Huntingdon, where they cover some rocks of very large size. Ordinarily palmately branching, their branches, 1 to 3 inches in thickness, are transversely undulated, cylindrical, or nearly square, and incurved on one side like a half-closed hand. As their substance is completely transformed into coarse sandstone, their form is generally obscure, and it is not possible to ascertain their true nature.

Though we do not admit these *Fucoides* as vegetable remains, we give the description of the two species as indicated by Harlan.

1. *Fucoides Alleghaniensis*, Harl., *Medic. Physic. Res.*, p. 392.—Frond compressed, wrinkled, recurved, obtuse; branches unequal, digitate or fastigiate, without nerves, canaliculate in the middle.

2. *F. Brongniarti*, Harl.—Frond large; branches nearly square, wrinkled across, compressed, and recurved. Probably this species is only a variety of the first.

THIRD CLASS.—*Muscites.*

In the introduction to this memoir, we mentioned our views about the distribution of the plants of this class, their mode of growing, and their participation in the present formation of the mineral combustibles. We can neither describe nor indicate a single species of moss found in the coal; but nevertheless we think that those plants were living with the ferns at the time of the coal-formation, and that we have found specimens belonging to the genus *Sphagnum*. They are in thin, yellow, very light slates, from the roof of the Gate Vein at Pottsville, looking exactly like pasteboard, entirely covered with faintly discernible, very small impressions, and crossed in every direction by flattened thread-like stems. The peat formed by the decomposition of the *Sphagnum* presents exactly the same appearance.

FOURTH CLASS.—*Calamariæ.*

The plants of this class, though found in great abundance in the Coal-measures, present a great difficulty in their examination; not only because they are always found in broken fragments, but because these fragments have never hitherto been found in such a state of preservation that their internal structure can be closely observed. These fragments also, though often belonging to the same species, present the greatest difference in their forms. We shall unite in this class, as M. Unger did, the *Calamites*, *Equisetites*, *Wolkmannia*, *Asterophyllites*, *Sphenophyllum*, and *Annularia*, without being certain, either that this place is the true one to which they belong, or that all the genera above mentioned belong to the same class.

That the *Asterophyllites*, as Messrs Lindley and Hutton supposed, are the branches of some species of *Calamites*, appears without a doubt. The external form, the leaves, the mode of branching, and the fructification, are perfectly visible in the small branches (*vide* Plate I., fig. 1, 1*a*, 2, 3), and may be sometimes followed in larger specimens. But these plants did not bear leaves, fruit, and branches, except when they began unfolding, or at their summits. Branches and leaves falling easily, the stumps were left entirely naked except at their summits, and, growing up, they enlarged themselves with the scars of the branches, and of the fruit, as is the case in indigenous plants. They may be compared in their mode of growing to some kinds of canes or bamboo. They were probably annual stems, with a very rapid growth; they became very high—from 30 to 60 feet—but not very broad, from 3 to 6 inches in diameter—and could consequently stand very near each other, and give, by their annual decay, a very large amount of material for the coal.

We have said that their place in the series of plants is undetermined. By their external form, they are evidently near the *Equisetaceæ;* but the fructification would indicate, as M. Brongniart has thought, that they belong to some kind of conifers related to the genus *Tanus* or Yew. As is apparent in our figure (Plate I., figs. 1, 2, 4), these plants were either diœcious or monœcious. The male flowers were terminal, and composed of an ear of appressed scales or united leaves, enclosing or supporting above them, small round cells, containing a pulverulent matter, probably the pollen (Brongniart, *Tableau,* p. 49). The true fruits—small, round, or obovate capsules—were born around the stems on the axils of the leaves, as indicated (Plate I., figs. 1, 2), and, by falling off, they left the scars ordinarily apparent around the stems of the calamites on the articulations—an organisation which is truly like that of some conifers.

Annularia and *Sphenophyllum* certainly belong to plants of quite another mode of growth. By the disposition of their leaves, which are always seen on a horizontal plane, they appear to have lived either on the water or on the mud, like our *Ayolla Caroliniana*, or more like the *Callitriche*, branching from the axil of the leaves, and extending in every direction. They have been compared to a phanogamous plant, the *Gallium*, but without any reason at all. The fructification of the *Sphenophyllum* much resembles that of the Asterophyllites, the ears only being smaller. It has been examined and described by M. Gutbier; but it is questionable if the ears represent the true fruit, or only the male flowers of these plants. The fructification of the *Annularia* has never been observed, but we think that it is attached under and around the leaves, as in the ferns. In the specimen represented, Plate I., fig. 5, the leaves are emarginate, slightly revolute on the margins, and perhaps this form is the fertile frond; the sterile one, with flat and pointed leaves, being figured in Fig. 5, a.

Many authors have supposed that *Asterophyllites* were the same plants as *Sphenophyllum*, floating partly immersed in water, becoming *Sphenophyllum* and enlarging the leaves when coming out of the liquid element. We cannot admit this opinion; but nevertheless we believe that *Sphenophyllum*, like all the plants which are living in water, have had different modifications of their leaves, without losing their general appearance. Our *Sphenophyllum trifoliatum*, Plate I., Fig. 7, is probably one of those abnormal forms which approach to an *Asterophyllites*.

I.—*Calamites*, Sûck.

Stems cylindrical, furrowed lengthwise, articulated, furrows either alternating or converging at the articulations; leaves encircling the stem like an open sheath; ramification either regular or irregular from the articulation scars of tubercles? marked above or below the point of attachment of the leaves.

1. *Calamites decoratus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 123, t. 14, Fig. 1-5.—Stem cylindrical; articu-

lations distant above (1 to 2 inches); approached below; ribs convex and thick; tubercles globose. South Salem coal, Pottsville.

2. *Calamites Suckovii*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 124, t. 15, Figs. 1–6.—Stem cylindrical, thick; articulations variable in length; ribs one-eighth of an inch broad, either convex, obtuse, or reeled; tubercles small ovate. Of this species we have two varieties: Var. A has the articulations distant, and the tubercles round. It is very abundant around Carbondale, where it forms a true forest of standing Calamites; the diameter of the stumps varies from 3 to 4 inches. Var. B has the ribs nearly plane, and the tubercles placed below and above the articulations. We found one specimen at the Gate Vein of Pottsville.

3. *Calamites ramosus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 127, t. 17, Figs. 5, 6.—Stems cylindrical, with distant articulations, bearing a half-spherical tumour at the base of solitary branches, with a hemispherical cavity on the articulation; ribs plane, one-eighth of an inch broad. Gate Vein at Pottsville in coal-slate.

4. *Calamites cruciatus*, Sternb., *Vers.* 1-4, p. 27, tab. 49, Fig. 5.—Stem cylindrical, with the articulations at the same distance, and a little convex; ribs plane and narrow; scars of branches on the articulations, either alone or verticulate; hemispherical, concave. Same locality as above.

5. *Calamites undulatus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 127, t. 17, Fig. 1.—Stem cylindrical, with distant articulations and plain flexuous broad ribs alternating in the articulations. A single specimen was found at the South Salem Vein, near Pottsville, in the coal-slate.

6. *Calamites Cistii*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 129, t. 20.—Stem thick, cylindrical, with articulations at the same distance; furrows very narrow; ribs half-round; tubercles globose. This species has been found at Wilkesbarre, and has been described by Brongniart, from a specimen sent to him; but we did not see this species anywhere, and all the specimens that we have seen around Wilkesbarre and Carbondale belong to *Calamites Suckovii.*

7. *Calamites dubius—Artis Antedil. Phitol.*, Fig. 13.—Stem cylindrical, with distant articulations; ribs parallel, about 1 line broad; furrows bistriate; tubercles ovate.

We refer to this species our No. 405 from Gate Vein, Pottsville, because of the bistriate furrows; but though our specimen is more than half a foot long, it has not any visible articulation. Perhaps it may belong to *Calamites remotissimus*, an undescribed species of Göppert.

8. *Calamites Cannæformis*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 131, tab. 21, Fig. 4.—Stem inflated above; upper articulations 2 to 3 inches distant, the lower ones scarcely 1 inch apart; ribs plane, slightly convex, a little flexuous, converging at the articulations.

Specimens of this species are in the collection of Mr Clarkson at Carbondale.

9. *Calamites pachyderma*, Brongt., *Hist. des Veg. Foss.* vol. 1, p. 132, t. 22.—Stem thick, with distant cylindrical articulations; ribs very broad, nearly plane, or slightly convex, unequal; tubercles obsolete.

The specimens referred to this species were found in the Conglomerates below the coal at Trevorton, and are not in as good a state of preservation as is wanted for an accurate determination. They agree at least in the broad nearly flattened ribs; but the articulations are very obsolete. This species is very large. We have seen, imbedded in the conglomerate sandstone, many of them nearly one foot broad.

10. *Calamites bistriatus*, Lesq.—Pl. II., f. 1.—Stems 3 inches broad, cylindrical; articulations equal, about 2 inches distant; ribs broad, nearly plane, narrowly ribbed again, converging at the articulations; tubercles very small and obsolete, inverted on the articulations.

A single specimen of this fine species was found at the Gate Vein, New Philadelphia. It is well marked by its striated ribs. These striæ are visible only on the barked part of the stem, the bark itself being nearly smooth.

11. *Calamites disjunctus*, Lesq.; Pl. II., f. 5.—Stem cylindrical; articulations distant about 2 inches, inflated and separated by a depressed furrow; ribs elevated, half cylindrical, exactly parallel, narrow surface, covered with very small elevated points which look like a powder; tubercles very small, round. This is also a very distinct species; found at the Gate Vein of Pottsville.

12. *Calamites approximatus*, Brongt., *Hist. des Veg. Foss.*, vol. 1. p. 134, t. 24, f. 7, 8. — Stem cylindrical; joints very near each other, slightly marked; ribs convex; tubercles either numerous and globose, or wanting.

This species is common in the coal-fields of Pennsylvania. We have found it at the Gate Vein, Pottsville, and at Tremont, and have seen beautiful and numerous specimens of it in the collection of Mr Clarkson, at Carbondale.

II.—*Equisetites*, Sternb.

Ear terminal and globose, superior sheaths, nearly immersed, and at length free, with pentagonal or concave scales very near each other; stem cylindrical, striated lengthwise, articulated, simple, branching below the articulations, and bearing erect-toothed sheaths, inserted below the articulations.

1. *Equisetites stellifolius*, Unger, *Gen. et Spec.—Pl. Foss.*, p. 60.

Equisetum stellifolium, Harlan.—Stem erect, simple, smooth, cylindrical, 1 to 8 inches in diameter; branches 10 to 12, emerging from the stem at the joints, like the rays of a star; articulations rather distinct near the base, approached above; sheaths indistinct.

We have mentioned this genus and this species only on account of the description of Harlan, which has been copied by the European authors without any criticism. The plant alluded to, and named by Harlan *Equisetum stellifolium*, is merely an Annularia—probably *Annularia fertilis*, Brongt. The error of those who have not had an opportunity to see the specimens is easily accounted for by the indication of the diameter of the stem, and of the mode of branching. What Harlan has named *branches* are the leaves, and his indication of the breadth of the stem, 1-8 *pal.*, which means the eighth part of an inch or a *line*, in French measure, has been translated 1 *to* 8 inches in diameter. Harlan remarks *that the articular sheaths which exist in all the recent species of this genus are barely visible in this fossil specimen; they may possibly have been destroyed by pressure; remnants of the sheaths are, however, visible.* There is not any trace of these sheaths in the fossil, and probably the author has taken some part of the leaves for them. The place where this species is indicated as found, is the Schuylkill anthracite. As we have had an opportunity of exploring carefully the anthracite basin of the Schuylkill, we have found there a great abundance of the *Asterophyllites* and *Annularia*, but never any trace of an Equisetites, and we have no doubt that Dr Harlan was mistaken in his observation. This conclusion is of great importance concerning the geological distribution of fossil plants; for it removes at once the *Equisetaceæ* from the Palæozoic coal, and shows their true place to be much higher in the geological series. *Equisetites mirabilis*, Sternb., is a stem of which nothing can be said, except that the class of plants to which it belongs is unknown.

III. *Asterophyllites*, Brongt.

Stems articulate, branching at the joints; leaves placed around the stems like the rays of a star (verticillate), open at the base, but often incurved above; equal, linear acute, single nerved, free or slightly joined together at the base. Fruit, axillary, monospermous (?) compressed nutlet, either naked or encircled by a narrow wing, which is pointed or acute at the summit. (For the male inflorescence, *vide* above, p. 849)*.——We have put together both the genera *Wolkmannia* and *Asterophyllites*, being unable to point out any peculiar marks to separate them.

1. *Asterophyllites gracilis*, Brongt., *Wolkmannia gracilis*, Sternb., *Vers.* 2, p. 53, Pl. 15, fig. 1–3.—Stem cylindrical, branching, leafy (articulations 2 to 6 lines distant), strongly furrowed in its length. Leaves verticillate, linear, obtuse, half an inch long, open on the stem, but straight, appressed together, short, and crowded near the summit of the branches, which terminate like an ear.——We have not found any specimen of this species in the coal-fields of Pennsylvania; but we have seen a beautiful one from Zanesville, Ohio, in the cabinet of D. Howart at Columbus.

2. *Asterophyllites equisetiformis*, Brongt., *Prod.* 159; *Hyppurites equisetiformis*, Lindl. and Hutt., vol. 2, tab. 192; *Bornia equisetiformis*, Sternb.—Stem a foot high and more, articulate, branching branches opposite, simple, articulated; leaves linear, lanceolate, single nerved; verticillate, inserted on the joints.——This species abounds in the anthracite basins. We have found stems of this plant, one inch thick and more, bearing leaves and branches. There is no difference between the American and the European specimens. Near the summit of the branches the articulations become shorter, and the leaves straight and appressed, and are longer than the space between the joints. In this state it is, we think, *Asterophyllites regida*, Brongt. *Prod.* p. 154.

3. *Asterophyllites foliosa*, Lindl. and Hutt., *Foss. Flor.* 1, t. 25.—Stem slender, striate, articulated, inflated at the joints; branches simple, either opposite or verticillate; leaves 8 to 10 in a whorl, linear, lanceolate, arched, single nerved, shorter than the distance between the joints.——This species is perhaps also a variety of the former; it scarcely differs, except by the leaves being a little broader and less numerous. Found at the Salem Vein at Pottsville, often mixed with the former. On the same slates we have also seen specimens agreeing exactly with *Asterophyllites tenuifolia*, Brongt., *Prod.* 159, and we think that this species belongs also to *Asterophyllites equisetiformis.*

4. *Asterophyllites crassicaulis*, Lesq.; *Annularia Longifolia* (?) Gutb., Pl. I., fig. 1—1*a*.—Stems thick, articulated, deeply striate; leaves verticillate on the joints, linear, lanceolate, acute, single nerved; fruit obcordate, acute, attached to the stems in the axils of the leaves.

We have found only two very small and broken specimens of this plant at the Gate Vein, New Philadelphia. It differs from all the species yet described, not only by its fruit, but by the thickness and the deep furrows of the stem. The fruits, or compressed nutlets, appear to be attached above the joints of the stems: they fill the whole space between the whorls of the leaves; but our specimens being too small and imperfect, we could not see the point of attachment of the fruits.

5. *Asterophyllites ovalis*, Lesq., Plate I., fig. 2. Differs from the former by its slender stem and slender furrows, the more numerous leaves, and the oval nutlets. Our small specimen is from the same locality as the former.

6. *Asterophyllites sublævis*, Lesq., Plate I., fig 3.—Stem thick, nearly smooth, or slightly undulate below and above the inflated joints, branching at the articulations. Leaves verticillate, half open, shorter than the distance between the joints; branches short, and thick with very short leaves.

The difference in the length of the leaves in this species may show how easily one may be misled in the determination of the species, in plants of which we have only the leaves to rely on as specific and distinctive marks. Taken alone, the branches with their short leaves would agree with *Asterophyllites delicatula*, Brongt., except for the thickness of the stems. The root (Plate I., fig. 9), which is on the same slate, appears to be the root of this Asterophyllites, and is very remarkable for its cuticle. The epidermis is covered with small undulate furrows, crossing each other nearly at right angles, and having the same appearance as the vessels in the internal structure of the wood of some coniferæ (Plate I., fig. 9, *a*). Sometimes the epidermis is found detached from the root, and an irregular surface remains; and in this case the resemblance to the vessels of wood is such that it may easily mislead the observer.

---

* M. Unger, who has not observed the fruits attached to the stem, says that they are encircled by an *emarginate* wing. He has seen them upturned. They are ordinarily pointed above, obcordate or emarginated below, and often bearing a short stem, in which case they belong to *Carpolithes bicuspidatus* of Sternb.

7. *Asterophyllites tuberculata*, Brongt., *Prod.*, 159; Lindley and Hutt., *Foss. Flora*, 1, t. 14, p. 45; 2, t. 180, p. 82; *Huttonia carinata* (?), Gutb.—Stem striate, distance between the joints very short; leaves short, obtuse, united together nearly to the summit, forming a thick ear, and enclosing small cells containing the pollen (?). Gate Vein of New Philadelphia, where it is abundant.

8. *Asterophyllites lanceolata*, Lesq.; *Wolkmannia major*, Gutb., Plate VII., fig. 32 (?)—This species differs from the former only by the leaves being united half their length, and terminated in a lanceolate point. In the same locality as the former, we have had opportunities for examining many specimens, and found this species a different one from any others.

9. *Asterophyllites aperta*, Lesq., Plate I., fig. 4.—This species, found also in the slate of the same vein of coal, has the ear more slender and longer than both No. 7 and No. 8. The leaves, though short, and united in their whole length, as in No. 7, are half open, and not appressed. When divested of its leaves it is deeply furrowed, and the joints, not inflated at all, are scarcely visible.

10. *Asterophyllites Brardii*, Brongt., *Prod.*, p. 159; *Annularia reflexa*, Sternb., 1 4, p. 31, t. 19, Fig. 5.—Stem striate, articulated; leaves in whorls turned backwards. We have seen some specimens of this species on slates covered with *Asterophyllites equisetiformis*, and think it the same species, the turning back of the leaves being probably accidental.

IV.—*Annularia*, Brongt.

Stems slender, articulated; branches opposite from below the base of the leaves; leaves verticillate, plain, often obtuse, single-nerved, of unequal length; fruit unknown.

Against the opinion of M. Unger, whose description of the fructification answers exactly to what we take for the male catkins of Asterophyllites, we persist in our opinion that these plants are not only different from the former, but belong to another class. For this reason we think that *Annularia longifolia*, described with the fruit, is a true Asterophyllites, and probably the same as *Asterophyllites equisetiformis*.

1. *Annularia minuta*, Brongt., *Prod.*, 155.—Stem striate, branching in whorls; branches branching again; leaves short, lanceolate. Gate Vein at Pottsville. Our species agrees with the description of Brongniart and the figures of Sternberg, except that in our specimen the leaves are slightly obtuse.

2. *Annularia fertilis*, Sternb., *Vers.*, 1 4, p. 31, t. 51, Fig. 2.—Stem (?); branches bearing about sixteen whorls, lanceolate, linear, slightly obtuse; leaves unequal in length, the lateral ones sometimes 1½ inches in length, and more. This species is commonly found in the highest and lowest veins of the anthracite basin—viz. in the South Salem coal at Pottsville, and the Mammoth Vein at Minersville, &c. We have received it also from many places in the coal-basin of Pennsylvania and Ohio.

3. *Annularia longifolia*, Brongt.—Stem thick; leaves verticillate, single-nerved, linear, lanceolate, numerous in the whorls. The thickness of the stems alone would be sufficient to detach this species from this genus. Gate Vein at Pottsville.

4. *Annularia sphenophylloides*, Unger, *Gen. et Spec.*, p. 68.—Stem diffuse, articulated, marked with deep but very narrow furrows; leaves verticillate, ten to sixteen; obovate, oblong, very entire, either slightly emarginated or pointed (Plate I., fig. 5 and 5 *a*). Very abundant in the slates of the upper coal-beds of the Pottsville anthracite basin.

The whorls of leaves are often found separate from the stem, and have been first mentioned as the corolla of some flowering plant. We have some doubt about the identity of the two forms, though they are ordinarily found together. As there is no other difference than the point of the leaves, we have thought it better to unite them, until it may be perhaps ascertained if the emarginate form is not the fruit-bearing plant, and the other the sterile one.

V.—*Sphenophyllum*, Brongt.

Stems simple, branching, articulated; leaves cuneate, verticillate by six to twelve, truncate at the apex, either serrulate, or bilobate, or laciniate, with linear narrow divisions. Fruit unknown. Messrs Presl and Germar have described the fruit as an axillar or terminal ear, composed of numerous bracteal leaves covering small nutlets, approached or united in four. Their drawings and description are truly remarkable, but the likeness of such ears to the male catkins of Asterophyllites (as said before) leaves a doubt upon this point. Perhaps these ears, which we have described as the male catkins of Asterophyllites, are the fruit of Sphenophyllum; but in this case Sphenophyllum would be the immersed part of an Asterophyllites, for we have seen those ears attached to the stems of these plants, and contrary to nature, the immersed leaves would be enlarged and many-nerved, and the aerial ones narrow, linear, and single-nerved. We cannot admit this conclusion. We have tried without result to solve satisfactorily this question. It is true that Asterophyllites and Sphenophyllum are ordinarily found together, and on the same slates, and often in such confusion that one of the plants looks as if it were the branches of the other; but a careful examination has always shown us both plants truly distinct and separate.

1. *Sphenophyllum Schlotheimii*, Brongt., *Prod.*, p. 68.—Stems 1 to 2 feet long, flexuous, striate, inflated at the

articulations; leaves in whorls of six, cuneate, nearly truncate or very obtuse at the summit; very finely crenate, open or reflexed; nerves furcate, terminating in the sinuses of the minute teeth.—Plate I., fig. 8, 8 *a*, 8 *b*.

At the South Salem Vein (new breaker), near Pottsville, the slates are entirely covered with this species, but we have never found there anything like the fructification described by Messrs Presl and Germar. The slates are often covered with small, round, deep, and hollow impressions, which look like the impression of a hard small nutlet; but they are obsolete, and their true nature cannot be ascertained. Our American species differs only from the European one by shorter, broader leaves, and by the stems being more inflated at the joints. In our Fig. 8 *b*, which represents the upper part of a stem, the leaves are nearly straight, and only three to four in a whorl.

2. *Sphenophyllum emarginatum*, Brongt., *Prod.*, p. 61.—Stem branching; leaves cuneate, crenulate, deeply emarginate, in whorls of six. Gate Vein at Pottsville.

3. *Sphenophyllum filiculmis*, Lesq.; *Sphenophyllites oblongifolia*, Gutbier; Plate I., fig. 6.—Stem very slender, thread-like; leaves in whorls of six, the lateral ones long, cuneate, deeply emarginate, and crenulate; inferior leaves much shorter, and a little broader, of the same form. This species, of peculiar appearance, and easily distinguished by the difference in the length of the leaves, and the slender stem, is the same, I think, that has been figured by Parkinson (*Organic Remains*) without any name. Its slender stem, the leaves expanded horizontally, and of unequal length, gives to it the appearance of a true Annularia.

4. *Sphenophyllum trifoliatum*, Lesq., Plate I., fig. 7.—Stem thick, inflated at the joints, striate; leaves in whorls of three, deeply cut in three linear acute divisions. The small specimen found and represented here does not give any hint about the general appearance of this plant. We think that we have in it a malformation of a Sphenophyllum caused by immersion.

5. *Sphenophyllum oblongifolium*, Unger, *Gen. et Spec.*, p. 70.—Leaves in whorls of six, oblong or ovate; denticulate at the apex, longer than the distance between the joints. We report with doubt of this species, of which we have not seen any figure. No. 127 and 129 of the Collection. Salem Vein at Pottsville.

FIFTH CLASS.—*Filices* (*Ferns*).

This class of plants, as every one knows, is the one of which the remains are most abundantly found in the Coal-measures. In the Palæozoic coal the number of ferns is such, that it was long an established opinion that all the plants of that epoch belonged either to this class of plants, or to the Equisetaceæ and Lycopodiaceæ, the two classes of vegetables nearest the ferns. We have already said what we think of this doctrine (see Introduction). This uniformity of vegetation is worth recollecting when we have a doubt about the classification of any peculiar genera of which there have never been found any specimens perfect enough to show its true place in the vegetable kingdom. Such is the genus *Noeggerathia*, admitted by Göppert, Unger, and the German authors to be a fern, and transferred by M. Brongniart to the class of the *Cycadeæ*. The presence of the plants of this genus in the Palæozoic formations below the coal, would of itself induce us to admit them as ferns. But, notwithstanding the scarcity of these plants, we have found many specimens of which the best part (figured, Plate I. fig. 10) shows evidently the same mode of branching as the ferns. The only difference that can authorise a separation of these vegetables from that class of plants, is the insertion of the leaves. But many species of *Sphenopteris* have the leaflets decurrent on the branches, and apparently slightly clasping, as in the Noeggerathia. This conformation is especially visible in our *Noeggerathia Bockschiana*, Plate III. fig. 1 *b*, 1 *c*, a plant related to the *Noeggerathia* by the disposition of the nerves, and to the *Adiantites* or *Sphenopteris* by the form of the leaves and the ramification.

To direct us in the study of the fossil ferns, there are very few characters on which we can rely with certainty. Though we have found many specimens of fossil ferns with fructifications (spore-cases or sporanges), the position of these fruits is the only character observable in them. Their form is always absolute; and the position itself, in connection with the veinlets, is mostly undefined, these veinlets being ordinarily obscured by the sporanges. Such being the case, we cannot admit the new classification of the fossil ferns as it has been attempted by M. Göppert, taking for its basis the form and the position of the fructifications. Relying only on what we can see on nearly all the leaves of ferns found in the coal, we take our marks or characters from the general form of the leaves and leaflets, and from the direction and the ramification of the veins and veinlets. The form of the leaves is so variable, not only on the same plant, but often on the same branch of a fern, that a classification with such a basis necessarily leads us into many mistakes. But the adoption of another method would not only expose us to as many errors, but especially lead to such a confusion of genera, by the obscurity and even the impossibility of description, that it is far better to adhere to the old method.

We have used the only means in our power of obviating the inconvenience of this method—viz. the study of the fossil ferns on the spot where they are found. We have never found any part of an interesting plant without looking carefully for other portions of the same, at the same locality, and very often have been enabled, by so doing, to rebuild a whole plant, the remains of which, found separately, would have certainly authorised the establishing of many species. It is by such researches that we were able to ascertain the identity of the genera *Cyclopteris* and *Neuropteris*, by following our *Neuropteris hirsuta* in all its transformations from the normal part attached to the stem, Plate III., to all the variations indicated on Plate IV. We have no doubt that all the stemless *Cyclopteris* with arched nerves belong to some described species of *Neuropteris*, and that all the stemless *Cyclopteris* with straight and diverging nerves belong to some species of *Odontopteris*. This opinion is elucidated in the description of the different species. From this point of view, if we had to make a general description of the fossil plants of America, we would necessarily unite under the name of *Cyclopteris*, all the species of *Neuropteris* and *Odontopteris*, of which the veins are slender and narrow, and the form of the leaves variable, from oval or lanceolate to circular. The following are, for the coal of Pennsylvania, all the species of *Neuropteris* which we have described, except *N. Cistii*, *N. Grangeri*, *N. heterophylla*, *N. minor*, *N. rarinervis;* all the stemless *Cyclopteris*, our *Odontopteris squamosa*, and perhaps *O. crenulata*, Bt. We would have naturally to make two divisions of this genus, one having the leaves with arcuate nerves, the other leaves with straight and diverging nerves. The *Cyclopteris*, with stem, belongs to another genus. Preserving, as we do, the classification generally admitted, we recognise only the three following sections in the fossil ferns—viz.:

1. *Neuropterideæ*, to which belong the genera *Noeggerathia*, *Odontopteris*, *Cyclopteris*, *Neuropteris*, and *Dyctiopteris*. 2. *Sphenopterideæ*, with the genera *Sphenopteris*, *Hymenophyllites*, *Pachyphyllum*, and *Scolopendrites*, two genera of which the true place is yet undetermined. 3. *Pecopterideæ*, containing the genera *Callipteris*, *Alethopteris*, *Pecopteris* and *Asplenites*. This last genus only is established on the form of the elongated sporangia.

1. *Neuropterideæ*.*—Frond pinnate or bi-pinnate. Secondary veins, either rising from a medial nerve, vanishing above, or all emerging and branching from the base without any distinct medial nerve. Fruits unknown.——It is truly remarkable that hitherto there has not been found any relic of the fruit of these *Neuropterideæ*, though the remains of ferns are very abundant in the coal. The impressions indicated by M. Brongniart, as being possibly the marks of the sporanges, on the leaves of *Neuropteris undulata*, have long since been acknowledged as accidental swellings of the epidermis. They are easily observed on many kinds of ferns belonging to this class, and even on the ferns of the other divisions. Possibly the *Neuropterideæ* had a fertile and a sterile frond like *Onoclea* or *Osmunda*, and perhaps also the fertile frond appeared and decayed before the complete maturity of the sterile ones, as it happens with our *Osmunda Cinnamomea.* Whatever it may be, the total absence of fructification in the plants of this class, both in America and in Europe, is a remarkable occurrence. In many places, especially at Pomroy, Ohio, we have seen the roof of the bed of coal entirely covered with the remains of *Neuropteris undulata;* in other places we have found the roof-slates so thickly covered with the leaves of *Neuropteris hirsuta*, or with those of *Dyctiopteris obliqua*, that the slates seemed like a mass of these leaves heaped upon one another; nevertheless we have not been able to detect any form that could be ascertained to be a fertile leaf.

I. NOEGGERATHIA, Sternb.—Frond bi-pinnately or tri-pinnately branching; branches elongated, obliquely attached to the stems; pinnules obovate, obcordate, or wedge-form, clasping or decurring on the rachis by their base, sometimes narrowed in a short petiole; nerves very numerous, equal, either simple or forking from the base up, parallel.

1. *Noeggerathia obliqua*, Göpp., *Gatt. Foss.*, Plates V. VI., tab. 12, fig. 2.—Frond bi-pinnate, pinnæ half open, attached to the stem in an acute angle, like the pinnules or the rachis; pinnules wedge-form or obconical, long, narrowed at the base, obliquely truncate at the summit; nerves dichotomous, distinct.——This species was found below Pottsville, in the Vergent strata. We cannot decide whether this species is the same as the one described and figured by Professor Hall in his geological report of the survey of New York, and named *Sphenopteris laxus;* or if the plant found by him belongs to the next species. We have also some doubt whether our American form is perfectly identical with the European plant of which the pinnæ have never been found, and the pinnules only been described. In our species the pinnæ are very long, we have only broken parts of them; the leaflets are from 1½ to 2 inches long, very obliquely attached to the rachis, and narrowed into a short and broad clasping petiole; the nerves flabelliform and dichotomous, distinct.

2. *Noeggerathia obtusa*, Lesq., Plate I. fig. 11.—Frond bi-pinnately branching; pinnæ elongated, slightly undulate; pinnules attached to the rachis in a very acute angle, broad and long, obovate, rounded or lobed above, narrowed below in a short broad petiole; nerves dichotomous and simple, parallel, distinct. Red sandstone of the Ponent group, Lehigh, below the Mauch Chunk Gap.——We have found this species only in small fragments on the same slates as the following; perhaps both belong to the same species. The nervation being alike in all our *Noeggerathia*, if we cannot rely on the form of the leaves for a specific character, we must have only one species of these plants. It differs from the following especially by its larger size, and the nearly round form of its leaflets.

3. *Noeggerathia minor*, Lesq., Plate I. fig. 10.—Frond bi-pinnately branching; pinnæ long and straight, half open; pinnules distant, small, obliquely attached to the rachis and slightly recurved, cuneate, very obtuse above, narrowed below; nerves very slender, scarcely distinct, dichotomous or simple and parallel. Same locality as the former.

4. *Noeggerathia Bockschiana*, Lesq., Plate III. fig. 1, 1 *a*, 1 *b*, 1 *c*, 1 *d*; *Cyclopteris Bockschiana*, Göpp. Uebers, p. 209; *Adiantites Bockschii*, Göpp., *Syst. Fil. Foss.*, p. 384, t. 36, fig. 6.—Frond bi-tripinnately branching; pinnæ nearly trifoliate or pinnated; pinnules obliquely attached to the rachis, varying from the obovate and obcordate to a broadly-cuneate form, narrowed into a short broad petiole, the upper leaflet larger and broadly obovate, and narrowed into a longer petiole. Nerves dichotomous and simple, very distinct; primary stem thick, channeled and slightly margined like the branches. In the Vespertine strata opposite Mauch Chunk this species affords the

---

* The definition of all the botanical terms used in our descriptions may be found in GRAY'S *Manual of Botany*. The word *frond* indicates the whole outline of a fern leaf. The frond is pinnate, or bi-pinnate, or tri-pinnate. The first division is the pinna, the last ones are the pinnules or leaflets.

best proof of the difficulty of a classification in the fossil ferns of this division. M. Göppert has seen only a leaflet of this plant, exactly like the one figured, Plate III. fig. 1 *a*. He placed it first in the genus *Adiantites*, and afterwards in the genus *Cyclopteris*. Considering the mode of nervation, the first place was the proper one for this plant; but by the nearly round form of the leaflet, it is a *Cyclopteris*. But the other parts of this plant which we have found and figured, would necessarily recall it to its former place. It is a true *Adiantites*, if we admit the genus as it has been fixed by M. Brongniart—viz. frond bi-pinnate or tri-pinnate, pinnules narrowed to the base, flabelliform, entire, with the veins diverging from the base without medial nerve. But as our plant has exactly the same nervation as the *Noeggerathia*, as the leaflets appear to have been joined to the rachis in the same manner as in the former species, and as the general form has nothing that departs from the other *Noeggerathiæ*, we have preferred to let it remain in this genus, the more so because our plant was found in the same strata as the other species. M. Göppert's plant, evidently the same as ours, was found also in the transition (Devonian) sandstone of Bohemia. This species has a great affinity with *Sphenopteris adianthoides*, Lindl. and Hutton, *Foss. Fl.*, 2, p. 115, t. 91 and 92; placed by M. Göppert among the *Cyclopteris*, it differs only in having equal nerves and enlarged petioles of the leaves.

II. Cyclopteris, Brongt.—Frond pinnate, leaflets sessile, flabelliform, half orbicular, sometimes round, sometimes also lobate, with a cordate and often unequal base: nerves numerous, flabellate, dichotomous from the base, nearly parallel; fructifications unknown. We shall separate this genus into three sections:—

α *Adianthoides*, with leaflets petioled, and nerves parallel and straight; a section which should be united with the genus *Adiantites*. β *Odontopteroides*, with round or cuneate leaves without petioles, the nerves diverging fan-like, dichotomous, and straight. The plants of this section are connected with some species of *Odontopteris*.

γ *Neuropteroides*, with the leaflets without petioles, the nerves furcate or dichotomous from the base, diverging fan-like and arched; a section which, as we have said above, should be united with the genus *Neuropteris*.

α Adianthoides.—1. *Cyclopteris flabellata*, Brongt.—Leaflets very entire, fan-like, round and undulate in outline, cuneate below; nerves very thin and close, straight, dichotomous, distinct. Tremont, New Vein. Our American species does not differ in any way from the one described by Brongniart, except that the nerves do not unite near the base in a thick fascicule. The leaves appear to have been borne on a short petiole. Related to this plant, we have a beautiful species of fern, found in abundance at Cuyahoga Falls, Ohio, and described by Prof. Newberry in the *Annals of Science*, No. X. p. 116, and named *Whittleseya elegans*, Newberry. It is a fan-like leaf, borne on a long petiole, cuneate, ovate below, equally cut, and serrate at the truncated summit. The very fine nerves, parallel and scarcely branching, if at all, are united in a fascicule at the point of the teeth, and diverging from the sinuses. These leaves plicate, fan-like in their length, had their surface deeply and equally undulate. This undulation, we think, has caused the obliteration of the nerves placed in the furrows, and the nerves of the elevated ribs alone are visible. This would account for the strange and abnormal appearance of these nerves, as indicated in the figure. We do not see on what ground it can be separated from the ferns, its likeness with some living *Adianthum*, especially with *Adianthum membranaceum*, being evident. We have never seen this species in the coal-basins of Pennsylvania.

β Odontopteroides.—2. *Cyclopteris fimbriata*, Lesq., Plate IV. figs. 17, 18.—Leaves nearly round or truncate at the base, where they are often unequally cordate or symmetrical; margins, especially above, fringed with long thread-like, linear, acute, flexuous, and nearly equal divisions; nerves flabelliform, dichotomous from the base, nearly straight, distant though very thin, parallel, ascending to the points of the divisions. Salem Vein, Pottsville. We have found many fragments of this beautiful species in the upper veins of the Southern anthracite basin; but we had an opportunity to study its general form in a beautiful specimen preserved by Mr Lawton at Barlow, Ohio, and also in another less perfect one in the cabinet of the Rev. Mr Brown, at Charlestown, Kenawha, Virginia. The species is remarkable not only for its regular fringe, but also for its nerves, which, branching from the base and from the middle, are parallel and simple above, and as distant as the divisions of the fringe. Except *Neuropteris crenulate*, Brongt., to which this plant has some affinity by the distance, the thinness, and the distinctness of the nerves, there is not any known *Neuropteris* with which it may be compared. Though we have many species of living ferns with fimbricate margins, it is the first time that a species of this form has been found in a petrified state, and from the old formations. But every day the study of fossil remains shows us something new, and teaches us that the primitive organic structures of this world were much more perfect than is generally believed. Truly each form of being was perfect from the first.

3. *Cyclopteris laciniate*, Lesq., Plate XIX. fig. 3.—Leaves orbicular quadrate, with the base equal and slightly cordate, irregularly fringed around by long, flexuous, acute divisions, somewhat unequal in length, and united in fascicules; nerves flabelliform, dichotomous, straight, very close and distinct. The surface is covered with a scaly coating, which entirely obliterates the nerves, but it falls easily into pieces, and beneath it the nerves appear perfectly distinct. We have found a single specimen of this plant at the vein of Muddy Creek, between Pottsville and Tremont, in connection with *Odontopteris squamosa*. The nervation of both plants is exactly alike, and also the scaly coating which covers them. This common character not observed on any other species, and the presence of these plants on the same slates, are, we think, sufficient proof that they belong to the same species of plants. And here already we have the first confirmation of our views about the identity of some species of *Odontopteris* and of *Neuropteris* with the genus *Cyclopteris*.

γ Neuropteroides.—4. *Cyclopteris undans*, Lesq., Plate IV. figs. 19, 20, 21, 22; and Plate V. figs. 1, 2.—

Leaves broadly oval or nearly round, emarginate at the base or irregularly cordate; margins undulate and irregularly serrate; nerves flabelliform, dichotomous, very slender and close, distinct, united in fascicules, and thickened at and near the base, arched. Gate Vein at Middleport. Following the transitions of forms between our figures 3 to 7, Plate V., there can be no doubt that all these leaves belong to the same species, and that our *Neuropteris undans* is the same as this *Cyclopteris*. All these leaves were found on the same slates, and all are identical, not only by their undulated outline, but especially by their thin close nerves, inflated at and near the base.

5. *Cyclopteris elegans*, Lesq., Plate V. fig. 4.—Leaves nearly orbicular, the lobes of the base converging and embracing the stem, and the point of attachment being nearly central; entire or slightly undulate in outline; nerves very distinct, deeply marked, radiate and dichotomous from the base, where they are thickened; arched. A beautiful species, easily distinguished by the thinness of the leaves, ordinarily slightly folded along the nerves, and especially by the sharpness of these nerves, ordinarily more arched to one side than in any other species. Found in the vein West of Shamokin, in connection with *Neuropteris tenuifolia*, Brongt., with which species it agrees in the thinness of the leaves and the sharpness of the nerves.

6. *Cyclopteris trichomanoides*, Brongt. — Leaves kidney-shaped or nearly round, either symmetrically or unequally cordate at the base; nerves very slender, distant, radiate, dichotomous, becoming very thin and close at the margins. We find in this species the same variety of forms as in the following, from which it differs only by the total absence of the hairs on the surface, and the nerves slightly thinner and closer on the margins. Found always in connection with *Neuropteris undulata*, especially at the Gate and Salem veins, Pottsville.

7. *Cyclopteris hirsuta*, Lesq., Plate IV., figs. 1 to 16; *Cyclopteris trichomanoides*, Brongt., in part; *Cyclopteris obliqua*, Brongt., *Hist. des Veg. Foss.*, i. 221, t. 61, fig. 3.—Leaves oval or round in outline, either symmetrical or unequally cordate, sometimes kidney-shaped, enlarged at the base with equal or unequal, either converging or diverging lobes; nerves very thin, radiate from the base, very close and slender near the margin; surface covered with short straight hairs about a line long. The monography of *Neuropteris hirsuta* gives a satisfactory reason for the new name adopted for this species. It is most commonly found in all the coal-basins of Pennsylvania, especially in the upper veins, as at Salem Vein, Gate Vein, at Pottsville, &c. We think that a few of the species examined and described by authors belong to this species, an accurate discrimination of them becoming impossible when the hairs, which appear to be very brittle, have disappeared.

8. *Cyclopteris orbicularis*, Brongt., *Hist. des Veg. Foss.*, i., p. 220, t. 61. fig. 12.—Leaves nearly round, slightly cordate, either symmetrical or oblique at the base; nerves very distant and strongly marked, dichotomous. Room Run Mines, above Mauch Chunk, in the lowest veins of anthracite. It appears to be the true species described by M. Brongniart, but does not resemble at all its synonyme *Adiantites cyclopteris* of M. Göppert, of which the nerves are numerous and close. In our specimen the nerves are fully one line apart, and many of them more distant, a little turned to one side. Mr Sternberg has described the rachis *thick and round.* We do not know any *Neuropteris* which might be related to this species, except perhaps our *Neuropteris fissa*, Plate III. fig. 2, of which the nerves are very distant, but thinner, and which has the leaflets concave, like this *Cyclopteris.*

9. *Cyclopteris Germari*, Göpp., *Syst. Fol. Foss.*, p. 218, Plate VII. fig. 1.—Leaves enlarged at the base, sessile on the rachis by the whole base, about round in outline, divided into two parts, the upper one lobate, with the lobes divided in from three to five lanceolate linear acute teeth; the lower part entire, with nerves emerging from the base along the rachis; dichotomous, distant, thin but well marked. A small specimen only of this remarkable species was found at the Salem Vein, Pottsville. The form of the leaves is as peculiar as the manner in which they are attached to the rachis, which is thick and narrowly striate. It is not possible to say anything more about this plant until we find some better specimens. By the form of the leaves it has some analogy with our *Neuropteris Desorii.*

III. Neuropteris, Brongt.—Frond pinnately or bi-pinnately divided; pinnules or leaflets cordate or nearly so at the base, scarcely narrowed, entire or cut-toothed, free or scarcely joined to the rachis by their whole base, and decurrent; nerves oblique, thinner above, either dichotomous from a medial nerve which disappears above the middle, or flabellate and dichotomous from the base. The definition of this genus somewhat differs from the one adopted by authors. The description of our species will show the reason of the difference. By limiting the genus *Neuropteris* to the species having a medial nerve, Messrs Göppert and Unger have been compelled to make different genera with different leaves of the same plant; and M. Brongniart himself necessarily admits in the genus *Neuropteris* many species which have no traces of a medial nerve.

1. *Neuropteris Rogeri*, Lesq., Plate VII., fig. 2.—Frond? leaves oval-lanceolate, cordate at the base, margin entire; nervules flabelliform and dichotomous from a scarcely-inflated medial nerve, distant, very slender and distinct, very arched downwards, and then turned upwards at the margin. Gate Vein, near Port-Carbon. Considering the leaves, the only part of this plant that we have been able to find, this species is the largest and the most beautiful of all. The leaves were of thin texture; the nerves, diverging fan-like and very arched at the base, are forking or dichotomous in ascending from a medial nerve scarcely more thick than its divisions. The nervules, though thin, are nevertheless strongly marked, and twice as distant from each other as in the following species. They approach only at and near the margin, where, changing abruptly their direction, they are curved upwards. We have found many specimens of this species, all at the same place, without any stem; they preserve well their specific characters. We have dedicated this species to Professor Henry D. Rogers, State Geologist of Pennsylvania.

2. *Neuropteris hirsuta*, Lesq., Plate III. fig. 6, and Plate IV. figs. 1 to 16; *N. cordate*, Brongt., *Hist. des Veg. Foss.*, p. 229, tab. 64, f. 5; Lind. and Hutt. *Foss. Fl.* p. 119, tab. 41; *N. angustifolia*, Brongt., *loco cit.*, i. p. 231, tab. 64, f. 8; *N. Scheuchxeri*, Hoffm.; *N. acutifolia*, Brongt., *loco cit.* i. p. 231, tab. 64, figs. 3, 4.—Frond bipinnate; pinnules trifoliate or simple; upper leaflets cordate at the base, lanceolate, acute or obtuse, sometimes irregularly lobed; all with a strong medial nerve disappearing above the middle; nervules furcate, very arched; pinnules of the base kidney-shaped, or round, or oval, much smaller, with the nerves fan-like and dichotomous from the base, without any medial nerve; surface of the leaves more or less hairy. The essential character of this variable species was first observed by Mr Bunbury, and mentioned in his description of the fossil plants of Nova Scotia,—viz., the short hairs scattered on the surface of the leaves. We have scarcely seen a well-preserved specimen on which these hairs were not observable with a lens. They appear, nevertheless, to have been brittle, and easily falling off; for sometimes there are only a few of them left on some part of a leaf, and sometimes they are numerous on the whole surface. This species is the most common of all in the coal-fields of Pennsylvania, from the lowest veins to the highest; and we have frequently had an opportunity of studying it where its remains were the only ones preserved. The short petioles, by which the leaflets are attached to the common rachis, have a peculiar structure. Being enlarged on the stem and pointed above, they stand on the rachis, ordinarily deprived of its leaves, exactly like thorns—Plate IV., figs. 15 and 16. The point of attachment of the leaves was so slender and brittle that we very seldom find any of the pinnules attached to the stem. We have seen them in this state only once or twice, among many thousand specimens that have come under examination. It is easy to follow the mutations of the form of the leaves and leaflets in our Fourth Plate; the basilar leaflets being indicated from N. fig. 6 to the *Cyclopteris*, figs. 13, 14. But the most remarkable of these transformations occurs in some of the upper leaflets, Plate IV., figs. 1 to 5. Near the summit of the pinnæ, the pinnules become simple, narrowly lanceolate (in which case they belong to *Neuropteris angustifolia*, Brongt.), and there they are sometimes cut in many lobes, either to the base or to the middle, preserving ordinarily a medial nerve in each division. The basilar leaflets, also, are sometimes diversely lobed, but they preserve always the flabelliform nerves diverging from the base, without any trace of a medial nerve. By following the series of transformations figured on Plate IV., it is easy to identify the genus *Neuropteris* with *Cyclopteris*, as we have indicated above. We have observed an analogy of form in the leaflets and some of the varieties above mentioned in *Angiopteris erectus*, Hoffm., of which we have seen beautiful specimens in the collection of Professor Asa Gray of Cambridge. *Neuropteris Scheuchxeri*, Hoffm., sent to M. Brongniart from Wilkesbarre, belongs probably to this species also; nevertheless, we have never seen a leaflet with the petiole attached to it as it is figured by this eminent author. The stems of this fern, narrowly ribbed but smooth, are sometimes very large; the one figured, Plate IV., fig. 16, was 3 feet long, and 3 inches broad; we saw it in the roof of an upper vein at Johnstown. We have seen still larger ones in the roof of the coal-seam mined at Pomroy.

3. *Neuropteris Clarksoni*, Lesq., Plate VI., fig. 1.—Stems irregularly bipinnately branching; pinnules simple, broadly lanceolate above, cordate or irregularly auriculated and hastate at the base, by the inferior lobe being more or less elongated; terminal pinnule lance-shaped, equally bilobed in the middle; nervules dichotomous, distinct, strongly marked from a thick medial nerve which ascends nearly to the summit. Collection of Mr Clarkson at Carbondale, where beautiful specimens of this species are preserved. This species, named in honour of Mr Clarkson, is somewhat related to *Neuropteris auriculata*, Brongt.; but it differs much from it by its thick and nearly continuous medial nerve, and by the outline of the upper leaflet, which has exactly the same form in all the specimens that we have seen. We would have admitted *Neuropteris acutifolia*, Brongt., as being probably a synonym of this species; but the author describes it *with nerves very thin and close*,—a character better agreeing with *Neuropteris hirsuta*, this species having the nerves thicker and more distant.*

4. *Neuropteris fissa*, Lesq., Plate III., fig. 2.—Frond (?) Pinnule oval, truncate at the base or cordate, with undulate margins; nerves dichotomous from a medial nerve, very distant and slender. Gate Vein at Pottsville. We have only the broken leaflet figured on Plate III. But this species is very peculiar and distinct by the distance of its undulate and scarcely-arched nerves obliterate above. The leaflet is concave, and the medial nerve appears to have been split by pressure. Its general outline is like *Neuropteris ingens*, Lind.; but in this species the nervules are thin and close, and in one species they are more than one line apart. Its affinity to *Cyclopteris orbicularis* is indicated, p. 856.

5. *Neuropteris smilacifolia*, Sternb., *Vers.*, i. pp. 29, 35; *N. acuminate*, Brongt.—Frond pinnate, pinnules alternate, opposite, petiolate, oblong acuminate, entire, from a slightly cordate base; nerves very thin and close, scarcely discernible. A single leaf of this species was found at an old shaft S.W. of Shamokin.

6. *Neuropteris plicata*, Sternb., *Vers.*, i. p. 16; ii. tab. 19, figs. 1, 3.—Frond pinnate or bipinnate; pinnules alternate, close to each other, ovate-acute, with a cordate base, the inferior lobe longer or extended; the margins undulate-plaited; stem round; medial nerves very slender; nervules numerous, arched, dichotomous. Salem Vein, Pottsville. We would have admitted this species as a variety of *Neuropteris undulata*, but for the nervules, which are finer and closer than in any other species of this division. We have figured Plate XX., fig. 4, the only specimen that we have found. We do not see any difference between this species and *Neuropteris obovata* of the same author.

---

* The analogy of this species with our living fern *Cassebiera hastate,* from Cape of Good Hope, is truly remarkable. The leaflets, both basilar and terminal, have the same variety of form and the nervation is alike.

7. *Neuropteris flexuosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 239, tab. 65, figs. 2, 3; and tab. 68, fig. 2.—Frond bipinnate, with long lanceolate-linear pinnæ; pinnules closely placed on the rachis, and their margins either continuous or imbricated, oblong, obtuse, very entire; the slightly cordate base parallel to the rachis, and the inferior lobe more or less dilated; terminal pinnule oval, angular, narrowed at the base; nervules very slender, arched, dichotomous from a medial nerve vanishing above the middle. Found everywhere in the whole extent of the coal-basin, especially in the upper veins. This species is very variable in the outline of its leaves; but it has always the inferior lobe of the pinnules more or less dilated. It is, in many of its parts, so very like *Neuropteris Loschii* that we much doubt if the species are not identical, this last one being the upper part of the frond of *Neuropteris undulata*.

8. *Neuropteris Loschii*, Brongt., *Hist. des Veg. Foss.*, i. p. 242, tab. 73.—Frond bipinnate; pinnæ sessile, nearly opposite or alternate, open, linear, lanceolate; pinnules alternate, close, or distant, cordate-oval, very entire; the terminal leaflet rhomboidal, and angular below the middle, larger than the lateral ones; medial nerve very slender, and nervules like the former species. See fig. 3, Plate XX. Our figure, which represents the upper part of a frond, shows how variable the pinnules are in their form.

9. *Neuropteris rotundifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 238, t. 70, fig. 1.—Frond bipinnate; pinnules very close to each other, and imbricated on the margins, round, oval, very obtuse above, short; medial nerve and nervules like the former. Gate Vein, Pottsville. Perhaps a variety of *Neuropteris flexuosa*, from which it differs only by the shorter, broader, and more obtuse leaflets, placed closer to each other on the rachis.

10. *Neuropteris tenuifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 241, t. 72, fig. 3.—Frond bipinnate; pinnæ long and linear; pinnules alternate, sessile, oblong, slightly narrowed and obtuse above, cordate at the base; the terminal one lanceolate, long, nearly pointed, angular near the base; medial nerve well marked, like the arched, dichotomous, and slender nervules. Shamokin, at a coal-bed west of the village. The terminal leaflet, by its lanceolate form, is characteristic of this species. The nervation is also peculiar. Vide *Cyclopteris elegans*, p. 856.

11. *Neuropteris gigantea*, Brongt., *Hist. des Veg. Foss.*, i. p. 240, t. 69.—Frond bipinnate; pinnæ nearly opposite, distant; pinnules alternate, sessile, oblong-obtuse, very entire, with a cordate, equal base; medial nerve thin; nervules numerous and thin, arched, forking. This species has been often mentioned as commonly found in the coal-basins of Pennsylvania. We do not doubt but that it has been confounded with *Neuropteris undulata* and *N. Loschii*. The only specimen of this species that we ever saw in the coal-fields of America is in the possession of Dr Howard of Columbus, and had been found at Zanesville, Ohio.

12. *Neuropteris Grangeri*, Brongt., *Hist. des Veg. Foss.*, i. p. 237, t. 68, fig. 1.—Frond bipinnate; pinnæ alternate, long, open, or slightly recurved; pinnules alternate, scarcely contiguous, ordinarily distant, oval, slightly enlarged at the base; nervules strongly marked, dichotomous, arched. A very fine species, related to *Neuropteris Loschii*, but easily distinguished by its oval leaflets, scarcely enlarged at the base, and by its fine and deeply-marked nervules. By its nervation it differs from the following species, to which Mr Brongniart thinks it might be allied. Very scarce in the anthracite coal-basins. Found once at Gate Vein, Pottsville.

13. *Neuropteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 238, t. 70, fig. 3.—Frond bipinnate (?); pinnules distant, oval, cordate above the base, and narrowed into a short broad petiole; nervules distant, thin, flattened, forking only twice. Gate Vein at Port Carbon—scarce. A species easily distinguishable by its leaflets borne on a broad base, and enlarged above.

14. *Neuropteris delicatula*, Lesq., Plate XX. fig. 2.—Frond bipinnate; pinnæ lanceolate, short; pinnules oblong, attached to the broad flattened rachis by their whole base, and slightly decurrent; nervules distinct, flabellate, dichotomous, arched, thin, and close; rachis slightly winged, flexuous. Salem Vein at Port Carbon. Though we do not like to increase the number of the species, and to admit any new one without being acquainted with it by the inspection of many specimens, we cannot but notice the small branch figured here; its nervation and the decurrent leaves on a broad nearly winged rachis is totally different from all the other *Neuropteri* of this section.

15. *Neuropteris Willersii*, Brongt., *Hist. des Veg.*, *Foss.* i. p. 233, t. 64, fig. 1. Plate III. fig. 3.—Frond bipinnate; pinnules obliquely placed, oblong, obtuse on one side; nearly perpendicular, longer, oblong, lanceolate, acute on the other; nerves flabelliform, dichotomous, crenate, slender, distinct and distant; rachis round, striate. Gate Vein, Pottsville. By the form of the leaves, longer on one side, shorter on the other, this species agrees with Messrs Brongniart's and Sternberg's figure and descriptions. We have nevertheless some doubt about the identity, on account of the peculiar nervation of this plant. Though very distinct and deeply marked, the nerves are thin and distant, and not at all thickened at the base; neither close on the margins, as these eminent authors have described their plant. The terminal leaflet appears very large; but it is broken through the middle in the only specimen that we have found, and we could not see its form.

16. *Neuropteris gibbosa*, Lesq., Plate V. fig. 3.—Frond bipinnate; pinnules nearly opposite, equally cordate at the base; oblong, obtuse, with the margins deeply and irregularly sinuate; nervules flabellate, dichotomous, very slender, close, and distinct. Salem Vein, Pottsville. A fine species, somewhat relative to *Neuropteris flexuosa*, but differing by its nerves, being thinner, closer, and flabellate, without any medial nerve, by the leaflets opposite, and the rachis round and inflated at the articulations of the leaves. At the base of some leaflets there are, between the nerves and following exactly their direction, some short, narrow depressions or holes, which, by their form and their symmetry, appear to have been of an organic nature. We could not ascertain whether they are not possibly the impressions of the fructification of these plants. These depressions are entirely naked.

17. *Neuropteris undans*, Lesq., Plate V., figs. 1 and 2.—Frond bipinnate; pinnules either large, 2 inches long and more, lanceolate, attenuate at the base, with the margins deeply undulate, plaited; or small, oblong, undulate, with a terminal pinnule, much larger and lance-shaped, obtuse, undulate, lobate, or angular below the middle; nerves flabellate, arched, dichotomous, very thin, and close on the margin, inflated near the base. Gate Vein, Middleport. This species is the same as *Cyclopteris undans*. *Vide* p. 855. The pinnules of fig. 9 are very small; but as the general outline is the same, and the nervation alike, we had no reason to separate it, the less so as this species offers us so many changes of form.

18. *Neuropteris crenulata*, Brongt., *Hist. des Veg. Foss.*, i., p. 234, t. 64, fig. 2.—Frond pinnate; pinnules alternate, sessile, oval-obtuse, denticulate, with an unequally truncate obtuse base; nervules furcate, slightly arched, distant and slender, from a slender medial nerve. We have found a single leaf of this species at the Salem Vein, Pottsville; but it is so well characterised by its distant, slightly-arched nerves, and its very small round teeth around the leaf, that we have no doubt about the identity of this species with the European one. —*Vide* Plate V., fig. 6.

19. *Neuropteris tenuinervis*, Lesq., Plate V., figs. 7 and 8.—Frond bipinnate; pinnules oval or oblong, with undulate margins, sometimes irregularly toothed at the summit, either regularly cordate at the base, or attenuate in a short broad petiole; nerves very thin, flabellate, dichotomous from the base, slightly arched, equal, not inflated below; rachis round, and narrowly striate. Gate Vein, Pottsville. There are in this species two characters which separate it from every other of this class; the form of the leaflets, which is very irregular and abnormal; and a very slender, deep, straight medial nerve, which looks nearly like a cleft along the pinnules, dividing them in two. This character enables us to identify both parts of this plant, figs. 7 and 8, which at first would appear as belonging to different species. This medial nerve is perfectly equal in its whole length, and ascends nearly to the summit. This species has some analogy of form with *Odontopteris subcuneata*, Bunb. (*Description of the Fossil Plants of Nova Scotia*); but our species has the nervules evidently arched, and is a true *Neuropteris*.

20. *Neuropteris dentata*, Lesq., Plate V., figs. 9 and 10.—Frond pinnate; pinnules slightly cordate, or irregularly truncate at the base; oval-lanceolate in outline, with the margins irregularly cut-toothed and lobed; nerves flabellate, dichotomous, arched, deeply marked, but very thin and close. Very scarce: found at Salem Vein, Port Carbon. This fine species has the most slender and narrow nerves of all. We have only a small part of a pinnæ, fig. 9, and probably a terminal leaflet, fig. 10.

21. *Neuropteris Desorii*, Lesq., Plate V., figs. 11 and 12, and Plate XX., figs. 5, 6, 7, 8.—Frond bipinnate; pinnules opposite, either oblong, oval, or obovate; entire, or irregularly laciniate and lobate, with the lobes sometimes pinnately divided in long and linear teeth; nerves flabellate, dichotomous, very thin above, thickened at the base. Salem or Gate Vein, West Wood. This species is certainly the most polymorphous in the whole class of *Neuropteris*. Though we have seen only the fragments figured, we do not doubt that all belong to the same species. Not only the nervation is alike, and all the varieties have been found on the same slates, but the analogy of form, and the transitions between them, are easily appreciable. As it happens in this section of *Neuropteris*, the leaflets at the upper part of the pinnæ become adherent to the rachis by their whole base, and are nearly decurrent and often contiguous. In this state the plant is very like the following one (*vide* figs. 11 and 12), but it differs always from it by its thinner and less distinct nerves. We have dedicated this beautiful species to our excellent friend Professor Desor, at one time actively engaged in the geological survey of Pennsylvania.

22. *Neuropteris heterophylla*, Brongt., *Hist. des Veg. Foss.*, i. p. 243, t. 71, 72.—Frond large, many times pinnately divided; interior pinnæ linear, sessile, the exterior ones bipinnate, petiolate, much longer; pinnules oval, or nearly round, obtuse, very entire, with a cordate equal base, terminal leaflet oblong, and much larger, medial nerve slender, nervules arched, dichotomous, distinct. It would be useless to enumerate all the forms and varieties of this species commonly found in the upper veins of the Anthracite Coal-basin at Pottsville, Westwood, New Philadelphia, &c. &c. The large frond is ordinarily three times divided; the last divisions or leaflets are either long and pinnately lobed, with the lobes separate nearly to the base, or united in their whole length; either simple, lanceolate, obtuse, or slightly acute, with two small round leaflets at the base. The strongly-marked nerves are characteristic of this species. One of our varieties presents exactly the form of *Neuropteris Brongniarti*, Sternb. It is distinguished by the longer, lanceolate, obtuse leaflets, sometimes slightly acute, either single, or with two small round leaflets at the base. This is the common form of the species in the upper part of the fronds.

23. *Neuropteris minor*, Lesq., Plate III., fig. 4.—Frond bipinnate; pinnæ short, linear, sessile on a thick, striate, round rachis, pinnatifid; pinnules oval, sessile, either separate, or united in the upper part of the pinnæ; terminal leaflet very small, oval; nerves thick, obsolete, bifurcate. Found at Tamaqua by Desor. Except the form of the upper leaflet and its size, this species agrees with *Neuropteris microphylla*, Brongt. The texture of the leaflets appears to have been thick; their surface is undulate and sometimes entirely smooth, the veins being indistinctly traced by the swelling of the parenchyma between them.

24. *Neuropteris rarinervis*, Bunb. *Quart. Jour. Geol. Soc.*, vol. iii.—Frond bipinnate; pinnæ long and linear, sessile, alternate; pinnules alternate, contiguous, oval, obtuse, slightly scythe-shaped, nearly cordate at the base, with the exterior lobe slightly extended; terminal pinnule deltoid, nearly trilobate. Superior pinnæ simple, linear lanceolate, with undulate margins, medial nerve distinct; nervules distant, bifurcate. Collection of Mr Clarkson, Carbondale. As Mr Bunbury observes, this species, in the form of its pinnules, is near *Neuropteris Loschii*

and *Neuropteris undulata;* but differs from both by its round narrow secondary rachis and its distant nerves. The nervules branch once only near their base—and the one division is simple; the other branches a second time near the margin.

25. *Neuropteris Moorii*, Lesq., Plate XIX., fig. 1.—Frond bipinnate; pinnæ nearly opposite, half open; pinnules alternate, ovate, slightly acute, entire, sessile by their whole base, and somewhat contiguous; nervules emerging either from the medial nerve, or from the rachis, furcate; primary rachis thick, smooth, winged by some pinnules of the same form attached to it. Found near Greensburg by the Rev. Mr Moore, in whose cabinet we were permitted to study it. A beautiful species, remarkable, like the following, for the leaflets being attached on the common rachis, and by the nerves emerging from the whole base of the pinnules. This character would be sufficient to separate these species into a peculiar genus, intermediate between *Odontopteris* and *Neuropteris.*

26. *Neuropteris adiantites*, Lesq., Plate XX., fig. 1.—Frond bipinnate; pinnules nearly decurrent on a slender rachis, oval, obtuse; inferior pinnules decurrent on the primary rachis; nerves dichotomous, distinct. We have only the upper part of a pinna found at South Salem Vein, Pottsville. It has a great affinity with the former, differing only by the thin rachis, and the oval form of the leaflets, of which the terminal one is very small. The veinlets are branching from a medial nerve, and dichotomous.

IV. ODONTOPTERIS, Brongt.—Frond bi-tripinnately branching, pinnules attached to the rachis by the entire base, oval, acute, or obtuse, thick; medial nerve slightly marked, nervules either simple or furcate, some of them rising from the rachis. The form of the leaves, as well as the nervation of many of the species of *Odontopteris*, evidently relates this genus to the former. Sometimes this relation is so near, that it is difficult to find any generic character to authorise the separation. Sometimes, also, as in the instance of *Odontopteris Schlotheimii*, this affinity totally disappears; hence a sectioning of this genus would be easy, and perhaps opportune. The first section would contain the species of which the nerves are close, flagellate, dichotomous, differing from the *Neuropteris* only by the straight direction of the nervules. To the second division would belong the species with distant and scarcely branching nerves, some of them rising from the base or from the rachis; and in this section, we think, the two last species of *Neuropteris* would take their place, as well as some of the *Adiantites* of M. Göppert.

1. *Odontopteris squamose*, Lesq., Plate XIX., figs. 2 and 2 *b.*—Frond tripinnate; pinnæ long, lanceolate; pinnules oblong, oval, obtuse, the terminal one smaller, oval, lanceolate, acute; nervules thin, but very distinct, flabellate, dichotomous, straight; surface of the leaves ordinarily covered with a coat of scales. At first this species appears identical with *Odontopteris obtusa*, Brongt., but by a close examination it is found to differ in many essential characters. As may be seen by the unfolded stem, the plant is tripinnate; the leaflets are longer and narrower, the layer of scales which covers the surface falls easily, and below it the nervules appear naked or strongly marked, though thinner than in *O. obtusa.* A scarce plant; found at South Salem Vein, Pottsville. Its analogy with *Cyclopteris laciniata*, is indicated, p. 855.

2. *Odontopteris Brardii*, Brongt. (?) *Hist. des Veg. Foss.*, i. p. 252, t. 75 and 76.—Frond bipinnate; pinnæ nearly opposite, and sessile distant; pinnules alternate, united together at the base, oval, oblong, acute, entire, slightly scythe-shaped, nerves very numerous, furcate, rachis round. We refer with doubt to this species a small specimen, No. 149 of the collection, which is very indistinct; it looks like a superior pinna, and has the pinnules slightly obtuse. Gate Vein, Westwood. A very scarce species in America, if present at all.

3. *Odontopteris crenulata*, Brongt., *Hist. des Veg. Foss.*, p. 254, Plate 78; *Neuropteris serrata*, Sternb., *Vers.* 2, p. 76.—Frond pinnate; pinnules alternate, lanceolate, acute, scythe-shaped, lobate, serrate; medial nerve slightly marked, nervules very thin, slightly arched, emerging from the striate rachis. Tremont New Vein. Our specimen, though small, agrees well with M. Brongniart's figure and description. It has a near affinity to our *Neuropteris dentata*, but evidently differs by the thin nervules being nearly straight, and rising from the rachis.

4. *Odontopteris Schlotheimii*, Brongt., *Hist. des Veg. Foss.*, i. p. 256, t. 78, fig. 5.—Frond tripinnately branching; inferior divisions pinnate, with the pinnules alternate, nearly round, or half round, entire, joined at the base; nervules thick and far distant, rising from the rachis, and nearly perpendicular to it; simple or furcate once only; superior divisions simple, with ovate, oblong, obtuse pinnules, twice as large, nerves dichotomous and slightly arched. Upper veins of the Anthracite coal, Salem Vein, at Pottsville, New Vein at Tremont.

This species, we think, is the same as the one described by M. Göppert, in his *Genera*, 5,6, tab. 6, and also the same as M. Brongniart's, though he says the nerves are very narrow and close (*tenuissimi* and *approximati*). This plant is very variable, either in the disposition and the size of the nerves, or in the form of the leaflets. Our fig., Plate VII., shows the upper part of a pinna, of which the superior pinnules have the form of a *Neuropteris.* On the inferior pinnæ, the short, half round, and sessile leaflets, have only a few nervules, thick, distant, straight, and scarcely branching; on the superior pinnules the nerves are flabelliform, dichotomous, slightly arched, and much closer. We have seen on one of our specimens the round, thickened, or inflated leaflets indicated by M. Göppert, as the fructifications of this plant. We think the appreciation of this able palæontologist is correct. As it occurs with the ferns of this class, the fertile plant is separate, and has a different appearance from the sterile one. In this species the primary rachis of what we think the fertile form is much thicker, deeply striate, with the branches attached perpendicularly, and sometimes recurved; some of the leaflets, round and inflated, do not present any trace of nerves, but only concentric lines; others of them are flattened, and have the normal nervation.

5. *Odontopteris dubia*, Lesq.—Frond (?) pinnule oval, lanceolate, entire on one side, pinnately divided on the other in three lobes, which are nearly distinct to the base, and oval; nerves numerous, slender, distinct, dichotomous.

We give under this name the description of a small specimen found at the Gate Vein, Pottsville, which may belong to some *Odontopteris* already described, either *O. obtusa* or *O. Sternbergii*, Göpp. It nevertheless differs apparently from both by the section of the leaflet on one side, the other side being entire and undulate—possibly one of those anomalies so often remarked in this genus, and only accidental.

V. Dyctiopteris, Gutb.—Frond bipinnate, pinnæ linear-oblong; pinnules sessile, oval-oblong, slightly and equally cordate at the base, obtuse and oblique, or a little scythe-shaped upwards; medial nerve disappearing above the middle; nervules much branching and reticulated by their diverging divisions. At first, by the reticulation of the nerves, this genus does not appear to belong to this class, but, by following the ramifications of the nerves, it is easily seen that it is identical with the nervation of a *Neuropteris*, with a difference in the divergence of the nervules. In many cases, especially in the largest leaves of our only species, the nerves are scarcely reticulated, and their divergence from the point of attachment is no greater than it is in a *Neuropteris*, and such leaves may easily be mistaken for those of this genus.

1. *Dyctiopteris obliqua*, Bunb., *Quart. Jour. Geol. Soc.*, vol. iii.—Frond bipinnate, pinnæ linear; pinnules cordate at the base, oblong-obtuse, slightly narrowed and scythe-shaped above; very deciduous, and attached to the rachis by the base of the medial nerve, which ascends only to half its length. This species is very abundant in both the lower and the upper beds of the coal-basins of Pennsylvania and Ohio. We have found it at the South Salem Vein, at Pottsville, and also at Trevorton. The pinnules, as it happens with many species of *Neuropteris*, are so very deciduous that they are scarcely found attached to the rachis. At Trevorton we have seen a thick bed of slates entirely formed of those pinnules, heaped one upon another, nearly without any trace of other fossil plants. We have figured, Plate VIII., fig. 6, a part of a pinna, that, we think, belongs to this species, in spite of the great difference in the form of the pinnules. The nervation is the same; such branches are found mixed with the pinnules of the normal form. There are found also many intermediate forms, and so we cannot admit it as a peculiar species. The medial nerve at the base of the leaflet is the mark by which this species is separated from *Dyctiopteris Brongniarti*, Gutb. Though the leaflets are ordinarily scythe-shaped in the American plant, this form is not without exception; it is also remarkable in the European species: they may prove identical.

II. Sphenopterideæ.—Frond bi-tripinnate or bi-tripinnatifid; pinnules sometimes entire, but mostly lobate, the lobes wedge-form at the base, dentate or diversely divided; nerves pinnate, with a primary nerve more or less distinct and flexuous; secondary nerves obliquely ascending, either simple in each lobe or division, or dichotomous, furcate at the apex; fructifications punctiform or marginal. This definition, nearly translated from Göppert's and Ungers, embraces the characters of this class of ferns, as we have admitted it; but we have never seen on any of our specimens a trace of fructification, and we can assert nothing either as to their position or their form.

I. Sphenopteris, Brongt.—Frond bi-tripinnate, pinnules lobate, wedge-form at the base, the inferior lobe ordinarily larger. Nerves pinnate; primary nerve more or less distinct, and ascending to the margin (decurrent); flexuous, secondary nerves dichotomous, branching two to three times in each lobe.

1. *Sphenopteris Darallia*, Göpp., *Gatt. Foss. Flor.*, i. p. 68, t. 11, fig. 23.—Frond tripinnate; secondary pinnæ alternately placed, linear, close, open; the inferior ones free at the base, the superior sessile and decurrent on the common rachis, six to ten parted; pinnules or lobes cuneate, round, emarginate above, terminal large; nerves two to three times furcate in each lobe. Kenawha Salines, Virginia; presented by Dr Hildreth, from Marietta. The only difference between the American plant and the species described by M. Brongniart is the greater size in all the parts of our plant. The frond is 4 to 6 inches long, the secondary pinna 1½ inch, with six to eight ranges of larger leaflets. As we have specimens of different sizes, this difference is probably accidental.

2. *Sphenopteris tenella*, Brongt., *Hist. des Veg. Foss.*, i. p. 186, t. 49, fig. 1.—Frond tripinnate, pinnæ and pinnules alternate, distant, petiolate, open; pinnules deeply pinnatifid; the inferior ones with two to three pairs of leaflets; the superior ones bi-trifid, with the divisions alternate, linear-lanceolate, acute, nerves pinnately branching, rachis filiform, naked. Gate Vein, Port Carbon.—A small specimen.

3. *Sphenopteris Gravenhorstii*, Brongt., *Hist. des Veg. Foss.*, i. p. 191, t. 55, fig. 3.—Frond tripinnate, with a broad and flattened rachis; primary pinnæ curved downwards; secondary pinnæ lanceolate, nearly equal, oblique on the slightly marginate rachis; pinnules small, oblique, ovate, three to five lobed; lobes short, bi-tri-toothed nerves nearly pinnately forking. Gate Vein, Westwood. A variable species. Sometimes the leaflets are longer, and the divisions broader. It appears to be common in the bituminous coal-basin, especially in Ohio. There are fine specimens of it in the beautiful cabinet of Professor Newberry.

4. *Sphenopteris Dubuissonii*, Brongt., *Hist. des Veg. Foss.*, i. p. 195, t. 54, fig. 4.—Frond bipinnate, pinnæ alternate, open, oblong-lanceolate, deeply pinnatifid; pinnules sessile, and nearly opposite, united at the base, short, nearly round, three to four toothed at the apex. Gate Vein, Port Carbon. In the American form, the secondary pinnæ are closer, a little longer, and the pinnules of the base ordinarily five-lobed. This character, and the scaly rachis, would place it with *Sphenopteris Hoeninghausii*, Brongt. (*Hist. des Veg. Foss.*, i. p. 199, t. 52). But the divisions of the pinnules are enlarged at the base, sessile by their whole base, and united together—(*neither separate nor narrowed*, as in this last species).

5. *Sphenopteris abbreviata*, Lesq., Plate IX, fig. 1, t. 1 *b*.—Frond bipinnate, pinnæ alternate, open, short, linear-lanceolate; pinnules alternate, sessile by the whole base, obliquely ovate in outline, crenulate; nerves pinnately

forked, distinct, rachis broad and smooth. Gate Vein, Port Carbon. The pinnæ are perpendicular to the rachis, as in *Sphenopteris palentissima*, Göpp., which our species resembles.

6. *Sphenopteris intermedia*, Lesq., Plate VIII., fig. 8, 9, 9 *a*. Frond tripinnatifid, rachis smooth and slender, slightly flexuous, secondary pinnæ linear-lanceolate, deeply pinnatifid; pinnules oval, decurrent, joined together by their base, serrulate at the summit; nerves obsolete, pinnately forked; nervules simple. Gate Vein, Westwood, and Tremont New Vein. This species is truly intermediate between *Sphenopteris chærophylloides*, Sternb., from which it differs by its longer secondary pinnæ, and the short pinnules united half their length, and *Pecopteris athyriodes*, Brongt., than which the secondary pinnæ are a little longer. There is also a slight difference in the less flexuous nerves, and in the pinnules, which are not so deeply toothed in our species; nevertheless, the affinity between them is so great that, but for the difference in their geological age, we would have admitted them as identical. It is abundantly found in the anthracite coal-fields of Pennsylvania.

7. *Sphenopteris flagellaris*, Lesq., Plate XVIII., fig. 1.—Frond bipinnatifid, pinnæ long, linear, flexuous, slender, pinnules alternate, oval, with a broad decurrent base, united together, crenulate; nerves bifurcate. South Salem bed, Pottsville. A species related to the former, but distinguished from it by its long flexuous pinnæ. It has also some affinity with *Pecopteris serra*, Lindley and Hutton.

8. *Sphenopteris plicata*, Lesq., Plate IX., fig. 3.—Frond bipinnatifid (?), pinnæ long, linear, pinnules distant, oval-oblong, enlarged below, sessile on the winged rachis, and united together, pinnately lobate, and undulate plaited; lobes short, a little obtuse; medial nerves thick; nervules obliterated or obsolete. Behind New Philadelphia, at an old shaft—probably of the Gate Vein. Though the specimen is imperfect, the species is evidently distinct and peculiar. We do not know of any already described to which it can be referred.

9. *Sphenopteris latifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 205, t. 57, figs. 1 to 6.—Frond tripinnate; pinnules short, petioled, ovate, pinnately divided; divisions oblique, oval, obtuse, two to three partite; nerves diverging from the bàse, many times forked, well marked, and thick. Salem Vein, Pottsville.

10. *Sphenopteris acuta*, Brongt., *Hist. des Veg. Foss.*, i. p. 205, t. 57, fig. 5.—Frond bipinnate, rachis slender, flexuous; pinnæ lanceolate, acute, oblique; pinnules lanceolate, five to seven lobed; lobes oval-lanceolate; superior acute, nerves very slender, flabellate, dichotomous, scarcely distinct. We have seen a fine specimen of this species in the cabinet of Dr Hildreth, at Marietta; found at Kenawha Salines, Virginia.

11. *Sphenopteris glandulosa*, Lesq., Plate IX., fig. 2.—Frond tripinnately divided, dichotomous, or forking at the top; primary and secondary pinnæ opposite, long, perpendicular, or recurved on the broad striate rachis; inferior pinnules equally three to five lobate, cordate at the base; lobes round, terminal leaflet acute, sometimes long-pointed by the persistence of the broad medial nerve; superior pinnules smaller, round, entire; all thick, convex, glandular-punctulate, rough; nervules entirely obsolete. A beautiful species found at Shamokin, west of the village. It is separated from *Sphenopteris obtusiloba*, Brongt., by its pointed terminal leaflet, and the glandular surface of the pinnules. It would agree by its ramification with *Sphenopteris Linkii,* Göpp., from which it differs however by its rough surface, and its much larger size.

12. *Sphenopteris decipiens*, Lesq., Plate XVIII., fig. 2.—Frond pinnate; pinnules elongated, pinnately lobed; lobes half round, very obtuse, decurrent, and united at the base, the terminal broader; medial nerve undulate, broad; nervules two to three times forked, slender, distinct. Shamokin Gap. At first sight this species is easily mistaken for both *Sphenopteris latifolia* and the upper part of the frond of *Alethopteris nervosa*, Plate XVIII., fig. 3. It differs from them both by its remarkable nervation. The nervules do not branch from the middle, but from the lowest nervule, which runs nearly parallel, and very near to the medial nerve.

13. *Sphenopteris polyphylla*, Lind. and Hutt., *Foss.*, Plate II., p. 185, t. 147.—Frond bipinnate or tripinnate, pinnæ alternate, open; pinnules alternate, petiolate, oval, inferior ones pinnatifid, superior trilobed, divisions round, ovate, entire, the terminal ones twice as large; rachis flexuous; nerves pinnate, forking near the margin. South Salem Vein, Pottsville. Scarce.

14. *Sphenopteris Newberryi*, Lesq., Plate IX., fig. 4.—Frond dichotomous, forking in a very obtuse angle, bipinnate, secondary pinnæ long, lanceolate, linear, acute, pinnately lobed; inferior pinnules sessile by their whole base, but distinct, irregularly undulate, lobate; superior ones confluent, oval lanceolate, entire, or slightly undulate, the terminal small and pointed; nerves obsolete. Found by a miner at Summit Mines, between Tamaqua and Mauch Chunk in the upper vein (red-ash coal; precise locality undetermined). A very remarkable species for its peculiar ramification. The broad rachis is flattened, or slightly marginate; the inferior leaflets are ordinarily larger than the other, and trilobate. It has some resemblance to the following species, and stands in the same division. Dedicated to our friend Professor Newberry, the palæontologist of Georgetown.

15. *Sphenopteris Lesquereuxii*, Newb., *Annals of Science*. *Vide* our Plate X., fig. 1.—Frond bipinnately divided; pinnæ alternate, long, flexuous, lanceolate; inferior pinnules cordate-oval, distant, pinnately three to five lobed or undulate; superior ones oval, or half round, confluent and decurrent, entire; nerves dichotomous, arched, obsolete medial nerve slender and undulate; rachis irregularly and deeply dotted or tuberculate. Room Run Mines, near Mauch Chunk. By its nervation this species resembles a *Neuropteris*, and would take its place in the genus *Adiantites*, as it has been characterised by M. Göppert. By the form of its leaflets only it has some affinity with *Sphenopteris latifolia*. It is common in the coal-fields of Ohio and Pennsylvania.

16. *Sphenopteris squamosa*, Lesq., Plate X., fig. 3.—Frond bipinnatifid; pinnæ linear, short, obtuse; pinnules nearly square, or half round, very entire, sessile; the superior ones confluent or joined together; terminal

leaflet large, lobate, angular, obtuse; nerves entirely obsolete, the surface appearing covered with small shining scales. South Salem Vein, Pottsville. The true place of this species is doubtful, the leaflets being thick and the nerves entirely obliterate, either by a thick parenchyma or something like a mat of scales. It was found in connection with *Dyctiopteris obliqua*, and resembles the upper branch of this species as we have figured it—Plate VIII., fig. 6.

17. *Sphenopteris artemisiæfolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 136.—Frond dichotomous, inferior pinnæ alternate; superior ones opposite, bipinnately divided; pinnules unequal, alternate, petiolate, obtuse, deeply pinnatifid, lobate, or laciniate; divisions linear or cuneate, with obtuse lobes; nerves numerous, flabellate. A small specimen of this species has been found near Pottsville.

II. Hymenophyllites, Göpp.—Frond membraneous, bipinnate or tripinnate, either irregularly cut, lobate, or pinnatifid and dichotomous, decurrent on the rachis. Nerves pinnate, excurrent, solitary in each division.

1. *Hymenophyllites furcatus* (?) Göpp., *Syst. Fil. Foss.*, p. 259; *Sphenopteris furcata*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 179, t. 49, figs. 4, 5.—Frond tripinnatifid, common rachis subulate, with its divisions nearly perpendicular, pinnules oblique, deeply pinnatifid, lobes bitrifid, the inferior ones nearly palmately divided, with the divisions linear-lanceolate, oblique, diverging, plane, and slightly acute or truncate. In the red shale of the Ponent Series south of Pottsville, and in the same formation near Mauch Chunk. In the American form of this plant, which may be a peculiar species, the lobes are scarcely acute, and often truncate. This fern appears to have been a very large one; it is mixed with stems, some of which are 3 inches in diameter, and apparently belong to the same plant.

2. *Hymenophyllites Hildreti*, Lesq., Plate IX., figs. 5, 5 *a*.—Frond bipinnate, secondary pinnæ lanceolate, open, alternate, the inferior bipinnately, the superior pinnately divided; divisions linear acute. Presented by Dr Hildreth, of Marietta, to whom we have dedicated this beautiful species, found at Kenawha Salines, on the lowest beds there exposed. It has some affinity with *Hymenophyllites obtusilobus*, Göpp., but the divisions in our species are evidently acute.

3. *Hymenophyllites capillaris*, Lesq., Plate IX., fig. 6.—The small specimen figured is scarcely worth a description as a peculiar species. It differs from the former by its very narrow and longer divisions. The ramification is not distinct. It looks at first like a branch of a *Sphenophyllum;* but it is a true *Hymenophyllites* by its nervation and its general outline. Found at the same locality as the former, of which perhaps it is only a variety.

III. Pachyphyllum, Lesq.—Frond large, thick, membraneous, oval or lanceolate in outline, either pinnately or irregularly lobed, radical, or borne on a thick rachis (?); divisions short, lanceolate, obtuse, or long, linear, flexuous. Nerves thick or compound, and parallel near the base; separating above, and solitary in each division, or disappearing totally. We have united in this genus a few species, of which the analogy with living ferns is scarcely known. Their affinity with the former genus is indicated only by the solitary nerve of each division; but beyond this these plants have nothing by which they might be related to the class of the *Phenopterideæ.* These plants, at least our *Pachyphyllum hirsutum,* may be compared to the family of the *Parkeriaceæ* in the living ferns—viz., to the inferior and sterile leaves of the *Parkeria pteroides*, Hooker, found in the marshes of Guyana. These inferior or sterile leaves are pinnatifid, with about three divisions, broadly oval in outline, and diversely lobed. The primary nerve is very thick near the base, simply pinnately branching at each division, quickly narrowing, and disappearing, like the secondary nerves, below the summit of the leaves. The divisions of the fertile leaves are narrow, linear, and much longer, and in these the veinlets are reticulated in an irregular, polygonal, oval, or square form, as they are in many of the leaves of the *Hypnaceæ* in the family of the Mosses. By comparison of the figure of Hooker and Greville, *Icones*, tab. 97, the likeness of the living species with our fossil plant is striking, and would evidently prove much more so without the thick coat of hairs with which our plant is covered. The affinity of *Pachyphyllum lactuca* with the other species of this genus is scarcely acceptable. Nevertheless, we think it much more in place in this genus than either in the *Schizopteris*, from which it evidently differs by its single-nerved lobes, or in the *Aphlebia*, which have no nerve at all.

1. *Pachyphyllum fimbriatum*, Lesq., Plate VIII., fig. 2.—Frond large, pinnate, pinnules sessile, distant, oblique, pinnately divided; divisions lanceolate, acute, short-fringed on the slightly-recurved margin; nerves pinnate, simple. Salem Vein, Pottsville.

2. *Pachyphyllum affine*, Lesq., Plate VIII., fig. 1.—Very like the former, differing only by the flattened and entirely smooth margins of the divisions. Perhaps only a variety. Same locality as the former.

3. *Pachyphyllum hirsutum*, Lesq., Plate VIII., fig. 3.—Frond bipinnately divided, dichotomous, pinnæ decurrent; divisions short, oval-acute; nerves obsolete, the whole surface and margins covered with long glandular hairs. Gate Vein, Westwood. A beautiful species, which, without its affinity with *Parkeria*, would scarcely be accepted as a fern. It appears to have had a thick medial nerve, and one nervule for each of the divisions of the leaves. It is a plant of the same kind as the two former. It may be compared with *Dictyophyllum rugosum*, Lind. and Hutt.; but we cannot see how it can be compared with a thistle, and classed among the dicotyledonous plants. It has the ramification of an endogenous plant.

4. *Pachyphyllum laceratum*, Lesq.—A species like the former, but smooth, and with the divisions undulate and unequally toothed. A small indistinct specimen, found at Johnstown, in the lowest vein of coal.

5. *Pachyphyllum lactuca*, Lesq., Plate VIII., figs. 4, 5.; *Schizopteris lactuca*, Sternb.—Frond pinnatifid (?), pinnæ lanceolate or oval in outline; pinnatifid, the lobes lanceolate, pinnately divided, divisions linear-obtuse; primary

nerves obliterate, appearing parallel and fasciculate below; simple in each division. Gate Vein, below New Philadelphia. This species was evidently of thin texture, and, by this character, would be well classed among *Hymenophyllites.* We have seen a broken specimen, three times as large as fig. 4, of which the leaves or pinnæ appeared as being attached to a broad common rachis, and through the impression of which the form of fossil ferns below it was discernible in their outline. The pinnæ were about half a foot long; but the slate was too brittle, and the specimen could not be preserved. This species is not scarce, either in the coal-formation of America or that of Europe.

III. Pecopterideæ.—Frond either simple, pinnate, bi-tripinnate, or bi-tripinnatifid; pinnules attached to the rachis by the whole of an equal or delated base, ordinarily united together, and very seldom attenuated; medial nerve strongly marked; secondary nerves or nervules ordinarily perpendicular to the medial nerve, or diverging from it, simple, and rarely forking or dichotomous, bi-trifurcate. Fruit-dots marginal, either attached to the nerves, and lengthened or punctiform. We have removed from this section all the genera admitted by Göppert, and characterised by the form and the position of the fructification, except one—*Asplenites.* In this genus only the form of the fruit-dots is evidently lengthened as in the *Asplenium*, and their form is easily discernible. But in every other specimen of fructified fern that we have found, we have been unable to find any reliable characters which authorise a separation from the genus *Pecopteris.* That this genus is overcharged with species that have no near affinity with each other, is evident. But the separation of the genera, determined by the form and the position of the fruit-dots, before the whole of a plant is perfectly known, causes only increased obscurity, and a useless multiplication of species, by compelling the admission of a fructified part of a fern into one genus, whilst the sterile part of the same is classed and described in another.

Asplenites, Göpp.—Fruit-dots linear, attached to the back of secondary nerves; nerves pinnate, nervules simple or dichotomous; frond pinnate or bi-tripinnate.

1. *Asplenites rubra*, Lesq.—Frond bipinnate (or tripinnate?); pinnæ broadly linear, half open, alternate; pinnules oval-oblong, united at the base; nervules forking from the base; fruit-dots linear, placed in two rows between the margins and the medial nerves; rachis thick. The remains or impressions of this fern cover of themselves a bed of red shale of the upper part of the coal-basin near Marietta, Ohio, in a depression of a rock named, from the presence of this fern, the Grotto of Flowers. It has a close affinity with *Asplenites nodosus* (Göpp.), and only differs from it by the stem being not inflated, and knotty at the articulations of the pinnæ, and by the nervules forking from the base.

Alethopteris, Sternb. and Göpp.—Frond bi-tripinnatifid or bi-tripinnate, secondary nerves rising perpendicularly or obliquely from the medial one, simple or dichotomous, and many times forking; margins of the pinnules often revolute (turned back). Fruit unknown.

1. *Alethopteris lonchitidis*, Sternb., *Vers.*, i. p. 21; *Pecopteris lonchitiea*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 275, t. 84, figs. 2, 3, 4, t. 128.—Frond bi-tripinnate; pinnæ open, alternate, the inferior ones bipinnatifid; the superior ones pinnatifid; pinnules open, alternate, lanceolate-linear, long, acute, slightly oblique, decurrent at the base, and united or distinct, convex on the margins; medial nerve broad, canaliculate, nearly excurrent; nervules perpendicular, slender, close, simple or dichotomous. Found in abundance in the lower beds of the coal-field of Ohio, especially at Cuyahoga Falls and Kenawha Salines, Virginia; and also in the upper beds of the anthracite coal at Pottsville. Gate and Salem Veins.

2. *Alethopteris Pennsylvanica*, Lesq., Plate XI., figs. 1 and 2.—Inferior pinnæ bipinnatifid, with short, round pinnules, united half their length; superior pinnæ pinnate only, with long lanceolate-linear and undulate pinnules, slightly decurrent on the rachis, and united at the base. Salem Vein, Pottsville. Perhaps this is only a variety of the former species, for it has exactly the same general appearance, and the same nervation. Nevertheless, as we have never seen, in the true *Alethopteris lonchitidis*, any trace of the lower bipinnate frond, and have never seen any undulate-serrulate pinnules, as figured in Plate XI., fig. 1, we could not unite the species. Both parts of the plant of Plate XI., figs. 1 and 2, evidently belong to the same fern; and we have here a confirmation of the analogy of this class of the *Pecopterideæ* with the *Pteris* of our age. In our *Pteris aquilina*, for example, the inferior pinnæ are bipinnatifid below, like our fig. 2, and only pinnate above. And on the same plant also the pinnules are found either entire, or undulate-crenate, like fig. 1.

3. *Alethopteris aquilina*, Göpp., *Syst. Fil. Foss.*, p. 298; *Pecopteris aquilina*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 248, t. 90.—Frond bipinnatifid; pinnules very open, close, oblong obtuse, united at the slightly-decurrent base, or sometimes separated to the rachis; the terminal leaflet oblong obtuse; secondary nerves perpendicular to the medial one, either bifurcate, or with one of the nervules simple. This species is often mentioned as being commonly found in the coal-basins of America; and we have seen many specimens under this name in Collections. Nevertheless, we could not find any well-characterised specimen of it, and all those which were shown to us under this name belong, we think, without any exception, to *Pecopteris polymorpha;* and so we mention this species with doubt as belonging to the American coal-formation.

4. *Alethopteris urophylla*, Göpp., *Syst. Fil. Foss.*, p. 300; *Pecopteris urophylla*, Brongt., *Hist. des Veg. Foss.*, i. p. 290, t. 86.—Frond bi-tripinnatifid; pinnatifid only above; terminal pinnæ linear, very long, entire, decurrent; inferior pinnæ deeply pinnatifid, terminated in a linear elongated leaflet; lateral pinnules united at the base, oblong linear, slightly obtuse; secondary nerves very thin, simple or dichotomous, slightly oblique. A small specimen found at the Gate Vein, Pottsville.

5. *Alethopteris Serlii*, Göpp., *Syst. Fil. Foss.*, p. 301, t. 21; *Pecopteris Serlii*, Brongt., *Hist. des Veg. Foss.*, i. p. 292, t. 85.—Frond bipinnatifid; pinnules oblong, oblique, enlarged and decurrent at the base, obtuse or slightly acute; terminal leaflet lanceolate; secondary nerves nearly perpendicular to the medial one, very numerous and thin, close, dichotomous. Both varieties of this species are abundant in the lowest veins of the Bituminous coal and anthracite basins of Pennsylvania. The variety α, identical with the European species, with obtuse leaflets, was found at Room Run mines, above Mauch Chunk, and at many other places in the Mammoth Vein; variety β, with the pinnules slightly acute, was found at Wilkesbarre, at Minersville, and also at the Kenawha Salines, Virginia.

6. *Alethopteris marginata*, Göpp., *Syst. Fil. Foss.*, p. 301; *Pecopteris marginata*, Brongt., *Hist. des Veg. Foss.*, i. p. 291, t. 87.—Frond bipinnatifid, pinnæ sessile, open, deeply pinnatifid; pinnules contiguous, oblong, slightly obtuse, decurrent, and united together, undulate-sinuate, and slightly emarginate; terminal leaflet oblong, lanceolate, obtuse; rachis and medial nerves rough; nervules very slender, perpendicular to the medial nerves, nearly simple. Tremont New Vein. In our specimen the pinnules are smaller, but probably represent the upper part of a frond; the leaflets are sessile, scarcely decurrent, and nearly distinct to the base.

7. *Alethopteris distans*, Lesq., Plate XII., fig. 2.—Frond bipinnatifid; pinnæ open, linear lanceolate; pinnules alternate, linear, distant, crenulate, enlarged but distinct at the base; united only in the upper part of the terminal pinnæ, where they become broader, shorter, and obtuse; secondary nerves obsolete. Found at Muddy Creek. We publish this species as a new one with some doubt, though we do not know anything for which it might be taken. It has a distant likeness to *Alethopteris Davrenzii*, differing from it by the crenulate leaflets. It may be also the upper part of the frond either of *Pecopteris abbreviata*, or of *Pecopteris plumosa*. As the nervules are entirely obsolete, and we can rely only on the form of the pinnules—a deceptive character—we cannot assert anything else except the peculiar form of these leaflets.

8. *Alethopteris obscura*, Lesq., Plate I., figs. 13, 14.—Frond bipinnatifid, pinnæ pinnatifid above; pinnules lanceolate, enlarged at the base, united together, and decurrent above, distinct below; deeply undulate on the margins, secondary nerves obsolete, very slender and oblique, bifurcate. Gate Vein, Pottsville. A beautiful species, distinct from all its congeners by the peculiar position of its secondary nerves rising from the narrow undulate medial nerve in a very acute angle. We have found only the specimens figured here, which probably represent the upper part of a frond.

9. *Alethopteris serrula*, Lesq., Plate XII. fig. 1.—Frond pinnatifid, very large; pinnules alternate, sessile, quite open, or inclined backwards; 4 inches long, and more linear, pinnately lobed; lobes alternate, two to three times toothed, sometimes nearly entire, obtuse; secondary nerves dichotomous, forking one or two times. Gate Vein behind Port Carbon. This remarkable species is related to *Pecopteris angustissima* and *Pecopteris similis*, Sternb., but perfectly distinct from both by the long leaflets, the lobes of which are once or twice toothed. The rachis is round and smooth. This fossil fern has so much affinity with *Davallia pinnata*, Der. (*Saccoloma pinnatum*, Presl.), that it is scarcely possible to find any difference between them. The fruit appears to be in the same position, and if this is the case, this plant would necessarily be far removed from the genus Pecopteris.

10. *Alethopteris nervosa*, Göpp., *Syst. Fil. Foss.*, p. 312.—Frond bi-tripinnate; pinnæ and pinnules nearly open; pinnules entire, oblique, oblong, lanceolate or oval, enlarged at the base, decurrent and united together; terminal pinnule oval, or linear oblong, the inferior leaflet of each pinna bilobate; secondary nerves distinct, oblique on the medial nerve, the inferior ones forking, the superior entire, thick. This species is abundant in the anthracite basins of Pennsylvania, at Shamokin, Pottsville, &c., and is very variable. Sometimes the leaflets are large and acute; sometimes near the top of the fronds the pinnæ are only pinnately lobed with round short lobes, entire, oval, obtuse, or slightly undulate. *Vide* Plate XVIII. fig. 3. We have had opportunities for finding it by itself on the same slate in its different varieties, and for ascertaining that the species described by M. Brongniart, and figured Plate XCV., figs. 1 and 2 of his *Hist. des Veg. Foss.*, belong truly to this, and not to *Pecopteris Sauveurei*, as has been asserted by M. Göppert.

11. *Alethopteris lævis*, Lesq.—Under this name, and till it is better known, we mention a form of which we could only obtain small specimens, and which does not appear to differ from the former, except by its entirely smooth surface, on which there cannot be seen any trace, either of secondary nerves or of medial ones. The pinnules are scarcely broader than in the former species, and the inferior leaflet is probably bilobed. Found at Gate Vein, New Philadelphia.

12. *Alethopteris muricata*, Göpp., *Syst. Fil. Foss.*, p. 313; *Pecopteris muricata*, Brongt., *Hist. des Veg. Foss.*, p. 352, t. 97.—Frond bipinnatifid or tripinnatifid, pinnæ or pinnules open, superior leaflets oval-lanceolate, acute, close, slightly decurrent at the base, the inferior ones distant, irregularly, pinnately lobed; lobes oval-acute, secondary nerves dichotomous, oblique on the medial nerve, simple or furcate. South Salem Vein, Pottsville. There is no difference between the American and the European form of this species.

III. Callipteris, Brongt., *Tab. des Veg. Foss.*, p. 24.—Frond bipinnatifid; pinnæ long, decurrent on the common rachis; pinnules contiguous, slightly oblique, united and decurrent at the base; medial nerve arched and oblique; secondary nerves oblique, bifurcate; fruit-dots punctiform, inserted on the divisions of the nerves near their bifurcation. We have adopted this genus as it is established by M. Brongniart, admitting in it only those species which have the nervation of *Neuropteris*, but which, by their general outline, and the punctiform fructification, belong to *Pecopteris*.

Callipteris Sullivantii, Lesq., Plate V., fig. 13.—Frond bipinnate, pinna lanceolate, pinnules alternate, oblique, obovate or oblong, nearly contiguous, slightly decurrent by their base, and united together with a slightly-obtuse sinus. Medial nerve very broad, disappearing above the middle; secondary nerves arched, slender, close, many times forking, or dichotomous. West Vein at Shamokin. A beautiful species, dedicated to our friend W. S. Sullivant, Esq., the well-known American Bryologist. The nearest species described is *Neuropteris conferta*, Sternb., of which M. Göppert has given a good description, with drawings (*Gatt. Foss.*, Plates V. VI., t. 8, 9, fig. 2). In our species the pinnæ are shorter, broader, and lanceolate; the pinnules are never separated to the rachis, and the superior leaflet is very small. The broad flat medial nerve vanishing above the middle is also a point of difference.

IV. Pecopteris, Brongt.—Fronds bi-tripinnate or pinnatifid, pinnæ ordinarily enlarged, united together, and decurrent at the base, or sometimes separated, distinct and sessile; secondary nerves rising obliquely from the medial one; dichotomous or simple; fruit-dots round, diversely placed, ordinarily two-ranked.

1. *Pecopteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 330, t. 106, figs. 1, 2; *Pecopteris pteroides*, Brongt., *Hist. des Veg. Foss.*, i. p. 329 (Tremont, roof New Vein); *Alethopteris Cistii*, Göpp., *Syst. Fil. Foss.*, p. 316.—Frond bipinnate; pinnæ and pinnules open; pinnules entire, oval, oblong, obtuse, free and sessile by the slightly enlarged base; terminal leaflet short, oval, the inferior attached to the common rachis at the base of the pinnæ; secondary nerves dichotomous, slender, the nervules forking. This species appears to be very scarce in the anthracite basins: it was sent to M. Brongniart from Wilkesbarre. All the specimens which we collected there, as related to this species, were, after a closer examination, referred to the following one.

2. *Pecopteris polymorpha*, Brongt., *Hist. des Veg. Foss.*, i. pp. 331, 332, t. 113; *Pecopteris Miltoni*, Brongt., *loc. cit.*, pp. 333, 114; *Cyatheites Miltoni*, Göpp., *Syst. Fil. Foss.*, p. 324.—Frond tripinnatifid; rachis smooth; pinnæ and pinnules open, alternate; pinnules slightly contracted at the base, close to each other, oblong, obtuse, the medial ones sinuate, the inferior pinnatifid; fertile leaflets longer, and somewhat crenulate; secondary nerves dichotomous, nearly perpendicular to the medial nerve; nervules simple or forking. Gate Vein, Pottsville, Muddy Creek, &c. Though we have found many varieties of this species, which is common in the anthracite basin, we could not observe a reliable character to separate it from *Pecopteris Miltoni*. We should even, perhaps, refer to it the following species.

3. *Pecopteris distans*, Lesq., Plate XI., fig. 3.—This differs from the former only by its distant pinnules, oval-lanceolate, narrowed at the base, and sessile only by the base of the thickened medial nerve. Same locality as the former. This species may perhaps be the same as *Pecopteris elliptica*, Bunb. (*Proc. of Geol. Soc.*, vol. ii. p. 84); but it differs by the veins, which are branching from the middle, or from the base; and by the leaflets, which are not decurrent on the stem.

4. *Pecopteris velutina*, Lesq., Plate XII., fig. 3.—Frond bipinnatifid; lower pinnæ very open; pinnate, short, linear-lanceolate; pinnules distinct, enlarged above the base, sessile, united only near the summit of the pinnæ, where they form a large lanceolate oval and lobate terminal leaflet; upper pinnæ simple, pinnately undulate, lobed or entire; nerves obsolete, the surface being covered with a coat of short appressed hairs; fruit-dots placed only at the upper part of the pinnules, few, two-ranked, large, oval. We have found at Johnstown, in one of the lowest beds of the coal, a beautiful and well-preserved specimen of this species. By the form of the leaflets only, it has some likeness with *Pecopteris Defrancii*, but it is a very different plant.

5. *Pecopteris ovata*, Brongt., *Hist. des Veg. Foss.*, i. p. 328, t. 107, fig. 4; *Alethopteris ovata*, Göpp., *Syst. Fil. Foss.*, p. 314.—Frond bipinnatifid; pinnæ linear, lanceolate, acute; superior pinnules oval, the inferior ones oblong, obtuse, convex, enlarged at the base, and united, the lowest leaflet attached to the common rachis at the base of the pinnæ; secondary nerves dichotomous, very thin, two or three times forked, attached to the medial one in an acute angle. New Vein, Tremont. In our American specimens the pinnæ are very long, pointed, and the terminal leaflet lanceolate. If this species is identical with the European one (only to be ascertained by a comparison of specimens), M. Brongniart has only seen or described the upper part of a frond, for in the inferior pinnæ the leaflets are much longer and narrower, resembling those of *Pecopteris Defrancii*. The nervation is perfectly alike in the American species, as described by M. Brongniart.

6. *Pecopteris notata*, Lesq., Plate XVIII., fig. 4.—Frond tripinnate; secondary pinnæ horizontal, short, linear-lanceolate, obtuse, sessile; pinnules short, oval, united nearly to the middle; terminal leaflet large, oval, obtuse; nervules strongly marked, one time forking, attached to the undulate slender medial nerve in an acute angle; rachis striate; fruit-dots very small, punctiform, irregularly placed along the nervules between the branches. The Gate Vein, Pottsville. The short and broad leaflets, and especially the strongly-marked though slender nervules, separate this species from the following. It is covered with small dots, pointing in relief on the surface of the leaflets, and irregularly placed between the nervules. We think that they are the impressions of fruit-dots. If we are right, this species would belong to the genus *Hemitelites* of Göppert.

7. *Pecopteris oreopteridis*, Brongt., *Hist. des Veg. Foss.*, i. p. 317, t. 104, fig. 2, and 105, figs. 1–3.—Frond bi-tripinnatifid; pinnæ and pinnules open, close, alternate; pinnules distinct, sessile, elliptical, obtuse; nervules forking from the base or the middle, oblique; fertile leaflets distant, longer, oval-lanceolate, with the margins recurved. The Gate Vein and Salem Vein, Pottsville.

8. *Pecopteris pusilla*, Lesq., Plate XI. fig. 4.—Frond bipinnate; pinnæ oblique, linear, nearly decurrent on a broad, flexuous, and winged smooth rachis; pinnules very small, united above the middle, oval, hairy, the lowest a little larger; nervules simple, obsolete. Salem Vein, Pottsville. It much resembles the smallest forms of the

following species, but differs in the hairiness of the leaves. It differs also from *Pecopteris villosa* by the smooth rachis and the small size of all its parts.

9, 10. *Pecopteris arborescens*, Brongt., *Hist. des Veg. Foss.*, i. p. 310, t. 101, 103, fig. 1.—Frond bipinnate or tripinnate, with a smooth-winged rachis; pinnæ long, close to each other, open; pinnules imbricated, but free to the base, equal, oblong, oval, short, and very obtuse; terminal leaflet larger; secondary nerves simple, oblique. It is commonly found in the upper beds of the anthracite coal, as at the Gate and Salem veins, at Pottsville, with both its varieties, *Pecopteris platyrachis*, Brongt. (*loc. cit.*, p. 312, t. 103, figs. 4, 5), which only differs from the normal form in the thickness of the rachis, and *Pecopteris dubia*, Lesq., which has the rachis covered with long glandular hairs.

11. *Pecopteris cyathea*, Brongt., *Hist. des Veg. Foss.*, i. p. 307, t. 101.—Frond bipinnate or tripinnate (?); rachis smooth; pinnæ and pinnules very open; pinnules unequal, very close to each other, linear-oval, obtuse, separated to the base; secondary nerves simple or forked once only, perpendicular to the medial nerve; fruit-dots two-ranked, small in the divisions of the nervules; fertile pinnules, with the margins curved backwards. A species commonly found in the upper beds of the anthracite basin, at the Gate Vein of Port Carbon, and scarcely distinguishable from the former.

12. *Pecopteris arguta*, Brongt., *Hist. des Veg. Foss.*, i. p. 303, t. 108, fig. 3; *Polypodites elegans*, Göpp., *Syst. Fil. Foss.*, p. 344, t. 15, fig. 10.—Frond pinnate; pinnæ open, straight, very long, close to each other; pinnules equal, contiguous, united at the base, linear, oblong, obtuse, undulate-plicate on the margins; secondary nerves simple, oblique, well marked, straight. The South Salem Vein, Pottsville; commonly found in the upper beds of the coal-basins.

13. *Pecopteris abbreviata*, Brongt., *Hist. des Veg. Foss.*, i. p. 337, t. 115, figs. 1–4.—Frond bi-tripinnatifid; pinnules oblong, obtuse, crenate, or slightly pinnately lobed; lobes round, convex, very short or longer, like pinnules; nerves pinnately forking in each division, ordinarily forking again from the middle. Found in the low beds of coal at Trevorton. A variable species. In our specimen the nervules are obsolete.

14. *Pecopteris unita*, Brongt., *Hist. des Veg. Foss.*, i. p. 342, t. 116, figs. 1, 5.—Frond bipinnatifid; pinnæ oblong, pinnatifid; pinnules united to the middle, sometimes in their whole length, so that the pinnæ are only crenulate on the margins; medial nerve of each pinnule oblique; nervules pinnate, simple, very oblique; fruit-dots simple two-ranked, attached on the simple nervules; fertile leaflets, with the margins recurved. Var. *α.*, pinnæ entire, and only crenulate on the margins. *Pecopteris unita*, Brongt. (*Prod.*, p. 58); var. *β. majus*, pinnæ pinnatifid, the pinnules united only to the middle. *Pecopteris pectinata*, Brongt. (*loc. cit.*), var. *α.*, at the South Salem Vein, Pottsville; var. *β.* Muddy Creek. In each of these varieties the fruit-dots preserve the same position.

15. *Pecopteris concinna*, Lesq., Plate XI. fig. 5.—Frond bipinnate; pinnæ open, with an undulate rachis; pinnules oval, lanceolate, sessile by a narrowed base, distant and perpendicular to the rachis; pinnately undulate, lobed; secondary nerves pinnate in each lobe; nervules simple. Gate Vein, Pottsville. A fine species, differing from *Pecopteris abbreviata* by the form of the pinnules, and from *Pecopteris angustissima* by its nervation.

16. *Pecopteris pennæformis*, Brongt., *Hist. des Veg. Foss.*, i. p. 345, t. 118, figs. 3, 4.—Frond tripinnatifid; pinnæ long, linear; rachis covered with small glandular points; pinnules slightly united at the base, elliptical, oblong, obtuse, perpendicular to the rachis; the lowest slightly longer; secondary nerves pinnately forked; nervules ordinarily forking again from the middle. Tremont New Vein.

17. *Pecopteris plumosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 348, t. 121, 122.—Frond tripinnatifid; pinnæ long, acute; superior pinnules united, triangular, acute, with the secondary nerves simple; medial pinnules oblong-triangular, more obtuse, enlarged, and united at the base, with the secondary nerves ordinarily forking; inferior pinnules oblong-obtuse, scarcely enlarged, and united at the base, very entire, the lowest oblong-linear, crenulate on the margins, distant, with all the nervules forked. Scarce in Pennsylvania; found only at the South Salem Vein, Pottsville.

18. *Pecopteris Sillimanni*, Brongt., *Hist. des Veg. Foss.*, i. p. 353, t. 96, fig. 5.—Frond bipinnatifid; pinnæ short, the superior entire, the inferior ones pinnatifid, seven to nine lobed; pinnules or lobes nearly round, obtuse, nearly contiguous; the lower distant, the upper ones united at the base; terminal lobe short, oval, entire, or three crenate; nervules very slender, forking one or two times; medial nerve scarcely more distinct than the lateral ones. Specimens of this species were sent to M. Brongniart from Zanesville, Ohio. We could not find any specimen of this species either in the field or in the cabinets which we have examined.

19. *Pecopteris Loschii*, Brongt., *Hist. des Veg. Foss.*, i. p. 355, t. 96, fig. 6.—Frond bi-tripinnate; pinnæ and pinnules shortening; inferior pinnæ bipinnate, with the upper pinnules united together; the medial ones separated to the narrowed base, and distant, ovate, acute; the lowest two five-lobed, nearly pinnatifid; nervules very slender, arched, forking from the middle. The Salem Vein, Pottsville. The American specimens of this species do not differ from the European.

20. *Pecopteris decurrens*, Lesq., Plate XI. fig. 5 *a*.—Frond bipinnatifid; pinnæ opposite, the superior ones terminal by the forking of the rachis; pinnules distant, oval-oblong, obtuse, entire, contracted at the base on the upper side; dilated on the lower, and decurrent on the rachis, which is broadly winged; medial nerve undulate, scarcely thicker than the lateral ones, which are simple, or sometimes forked and arched; primary rachis flattened and broad, enlarged at the articulations of the pinnæ, striate; and roughened by very small glandular points. The Gate Vein, Pottsville. A remarkable species, which does not well agree with *Pecopteris*, and should be taken as the type of a peculiar genus.

21. *Pecopteris incompleta*, Lesq., Plate I. fig. 12.—Frond bipinnatifid; pinnæ oblique, scarcely open, lanceolate; pinnules oval, or nearly round, decurrent, united at the base, very oblique; the superior ones very small, and the terminal wanting, its place being taken by the lengthened secondary rachis pointing above the leaflets; nerves dichotomous. The small specimen figured here was found at the Gate Vein, Pottsville. It is so imperfect that we cannot ascertain whether it represents only a part of a fern before its complete unfolding, or if this peculiarity of form belongs to a species in its state of perfection.

FERNS OF UNDETERMINED AFFINITY.

Crematopteris, V. P. Schimper.—Frond simply pinnate, rachis broad; pinnules vertical, oblique, oval-oblong, entire; nervation obsolete. Fruit-dots placed on the inferior pinnules, which are turned backwards, and are smaller than the upper ones. This genus has been established for a single species found in the red sandstone of the Vosges, *Crematopteris typica*, Schp. and Mouzeot, *Monog. of Fossil Pl.*, p. 73; *Filicites scolopendrioides*, Brongt., *Hist. des Veg. Foss.*, i. p. 388, t. 137, figs. 2, 3. Its relation with *Pecopteridiæ* is not ascertained, as there has not been found any trace of nervation in these plants.

1. *Crematopteris Pennsylvanica*, Lesq., Plate III. fig. 5.—Rachis very thick, round, nearly smooth, or irregularly striate; pinnules short, linear-oval, distant, sessile on the broad rachis, slightly attenuated at the base; nerves entirely obsolete. The specimen figured here is in the collection of Rev. Mr Moore of Greensburg, and was found by himself near this place in black shale, covered with marine shells, a little above the fourth vein of coal, and at the base of the Barren measures. This plant is not in as good a state of preservation as would be desirable for a satisfactory description; nevertheless it appears to belong to this genus. Its presence on a shale covered with marine shells would perhaps lead to the supposition that the plant is some *fucoide*, or sea-weed. We have examined closely the locality, and have been able to find there many other vegetable remains, all of them belonging to ferns and to calamites, especially a *Sphenopteris.*

Scolopendrites, Lesq.—Frond simple, lanceolate, large, deeply irregularly toothed; medial nerves very slender; nervules thin, pinnately forking from the medial nerve in a very acute angle, nearly straight and scarcely arched, undulate, very distant, one to two lines; forking one time in the middle, and each nervule forking again near the margin. This genus has no affinity with any of the other genera of fossil ferns. In the form of the leaves it would resemble the living *Scolopendria* of our time, but its nervation is different, the medial nerve being much more slender, and the nervules much more erect, or not so divergent from the medial nerve. Nevertheless the divergence of the nervules is less marked in some species of the genus *Scolopendrium*, as in *S. hastatum*, Duby; and also *S. hemionitis.* The general outline of the leaves of *Halypteris scolopendrina*, Hooker, and *Vittaria isoctifolia*, is also much alike; but the veins are simple in both these species, and more diverging. This plant, by its nervation, resembles perhaps some species of *Osmundæ* with large leaves—the largest leaflets of *Osmunda regalis*, for example. But its affinity with this genus is not so close as with the former ones, and as we cannot compare it with any other, we have preferred to name it after the living genus, which it resembles in the form of its leaves.

1. *Scolopendrites grosse dentata*, Lesq., Plate VIII. fig. 7.—The species corresponds to the description of the genus of which it is the type. The texture of the leaves was very thin, entirely smooth and shining, and its size probably large. We found a few specimens of it at the Gate Vein, New Philadelphia; but the shale being very brittle, we could not preserve a better specimen than the one figured here. Many of these leaves, of which the outline was obliterated, appeared wrinkled, as if they had been crushed in no one given direction.

STEMS.

The true relation of some of the stems found in the coal, with their branches and leaves, is indicated either by their form or by the situation in which they have been found, and also by the branches attached to them. This is the case, for example, with the *Calamites.* But when we come to the examination of most of the large trunks or stumps found in the coal of transition, we are only able to assert, by the impressions of their bark, either that they belonged to the bark of some fern tree, or to some genus of plants resembling the *Lycopodiaceæ* of our time. The study of those trees which are sometimes found well preserved in a petrified state is now satisfactorily progressing, by the examination of the internal structure of the wood. But this examination is possible only with the aid of a strong microscope, or very thin polished plates of the matter. As we have not until now had the facility for preparing these plates, and as all the petrified wood which we have seen in the coal-basins of Pennsylvania has been transformed into sandstone, and its vessels entirely obliterated, we can only rely for our descriptions on the prints left by the base of the leaves on the bark of those trees, and not attempt a classification fixed on other characters.

For the facility of our descriptions we shall separate all the vegetable remains which have not been mentioned above, into three classes,—1st, *Stems;* 2d, *Fruits;* 3d, *Roots.*

1st, Stems.—In the slates covering or supporting the coal, nothing remains of the trees which have been heaped for the formation of the coal except the impressions of their bark. We have given in the introduction such reasons as we could for the explanation of this remarkable phenomenon. Sometimes, it is true, the form of a tree is preserved entire, but this is seldom the case; and when it happens in the sandstone, the woody matter has entirely disappeared, and been transformed into sandstone, and the mould only of the external form remains marked upon the stone. Many of those trees became very large, and the impressions of their leaves, very small at first, but growing up and enlarging with them, and undergoing some modifications, may lead the observer into some unavoidable mistakes. As soon after as it was possible, we have compared specimens of different ages, and our descriptions of new species are exclusively in accordance with the form, but never with the size, of the impressions.

I. Caulopteris, Lind. and Hutt.—Stem very thick, tree-like, round, marked without with large scars left by the insertion of the petioles of leaves; scars disposed spirally, oblong, oval, with a broad double or simple margin (annulus), marked in the middle by a fascicule of vessels—simple, oval, or curved above, horn-like. In the species belonging to this genus, which, as we have asserted, contains the *Ptychopteris*, *Stemmatopteris*, and *Caulopteris* of Corda, the scars are ordinarily obsolete, and sometimes covered with the rootlets attached to the stem. The true form of the fascicule of vessels is visible only on one scar of our fig. 1, Plate XIII., in *a*, and it is easy to see how it has been overlooked till now, this form becoming entirely changed by the obliteration of the horns. Following the observations of Mr Lindley, and other authors, the scars in this genus are identical with those left on the stems of the tree-ferns by the falling of their leaves.

1. *Caulopteris punctata*, Lesq., Plate XIII., fig. 1.—Scars oval, obtuse, about 2 inches long, distant, with a broad smooth margin; fascicule of vessels simple, oval, forming the margin, and curved above in two horns. Interval between the scars thickly dotted with round elevated points resembling glands, but probably the base of small rootlets. A beautiful species found at the Gate Vein, New Philadelphia.

2. *Caulopteris gigantea*, Lesq., Plate XIII., fig. 2.—The difference between this species and the former is not only in the larger size of the scars, but in the entirely smooth surface, and the divergence between the horns of the vascular fascicule. The small specimen figured here is preserved in the beautiful collection of Mr Clarkson at Carbondale.

3. *Caulopteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 418, t. 140, fig. 2.—In this species the form of the vascular fascicule is entirely obliterated; but it differs evidently from the two former by the intervals furrowed in the length—the scars being more distant, with a broader margin. It has been found at Wilkesbarre, sent to Europe, and described by M. Brongniart. We have not seen any specimens of it.

II. Psaronius, Corda.—Stem thick and tree-like, cylindrical or angular, externally marked with scars, the form of which is obliterated by a thick coat of rootlets covering nearly the whole stem; bark thick and hard. The internal structure of these trees is beautifully illustrated and described by M. Corda in his *Beytrage*. These fossil remains represent, we think, the petrified root-stalk of some large ferns, and do not belong, as M. Brongniart supposes, to the *Lepidodendron*. They are found in great abundance in some places, always in short thick stumps, which, either by the rootlets with which they are covered, or by their form and their internal structure, resemble the short trunks of large ferns as they are found in the tropical islands, especially on the mountains of Java. We cannot describe any species of this genus for the reason mentioned above—viz., the impossibility of polishing thin plates of them for microscopical investigation. But it is necessary for us to mention this genus, for the abundance of the specimens found in the coal-basins, and for their peculiar situation. Their place, wherever they have been found, is at the base of the Barren measures, a little above the fourth vein of coal, and very near the slates covered with marine shells and impressions of fern. There are a great many specimens at Greensburg, in the cabinets of the Rev. Mr Moore, and of Dr King, and especially at Marietta, in the beautiful cabinet of Dr Hildreth. These latter have been found near Athens, Ohio, but the others were collected around Greensburg, Pennsylvania. The specimens of Ohio are entirely silicified; and those which Mr Hildreth has had polished in Europe present as fine an appearance as the most beautiful agate. We have seen *Psaronius* also at Charlestown, Virginia, on the Great Kenawha Saline, and at Gallipolis, Ohio.

III. Diplostegium, Corda, *Beytrage*, p. 112.—Stem thick, tree-like, equal, round, marked with elevated scars, very near each other, and spirally; top of the elevated scars abruptly cut, rhomboidal.

1. *Diplostegium Brownianum*, Corda, *Beyt.*, p. 112, tab. 59.—This species is the only one of the genus described. It much resembles a *Knorria*, except that the elevated scars are abruptly cut and transversely broken, and not rounded at the top. We have found a specimen of this species at Summit Portage, below the Ponent, in a bank of sandstone, containing also large bivalve shells. Our species agrees well with the one described by M. Corda.

IV. Stigmaria, Brongt.—Stems creeping, 2 or 3 inches in diameter; dichotomous, covered with leaf-like round appendages, either simple or forking; slightly contracted at the base, with a single central vascular fascicule; scars round, with a double ring and a single elevated point (mamilla) in the middle. Every author who has studied the fossil plants has had a peculiar opinion about these fossil remains, the most abundant of any in the Coal-measures. It has been asserted, on the observations of Mr Joseph Hooker especially, that they were the roots of a peculiar genus of trees—probably the Sigillaria. We have had many good opportunities of examining large specimens of these vegetable remains in the coal-basins of Pennsylvania, and we have come nearly to the same conclusion. Near Minersville there is a flattened rock, entirely covered with *Stigmaria ficoides* on a surface of about 70 feet long and 25 broad. All the branches are nearly equal in diameter, and all dichotomous or forking, and, forking again, extending themselves in every direction, and evidently creeping on the mud or on a soft ground, where their rootlets or leaves supported them. We cannot say, with Messrs Lindley and Hutton, that they are coming out from a common axis; but that, at their point of union, they support a trunk of *Sigillaria*, or of another species of tree. At Minersville there is no trace of such an axis, but it has been observed many times; and we have ourselves seen, in the collection of Mr Moore, a beautiful specimen, illustrating the manner of branching of the roots from the tree. The stump is about 6 inches in diameter, with pretty large scars, and divided below into three diverging branches, of which the diameters are about a third of the diameter of the trunk, and of which the scars are slightly smaller, and of nearly the same form. As the specimen is a mould in the sandstone, the scars, which appear triangular, are not very distinct. This disposition of long creeping root-stalks is in perfect accordance with the places which the vegetables forming the coal occupied. It was the only one which could be devised to sustain large trees on a soft and ordinarily inundated ground. It explains the disproportion in the scarcity of trees with the great abundance of *Stigmaria;* for these plants having a growth by themselves, and probably nearly independent of the aerial plant or the tree, as is the case in some creeping and running plants, were extended in every direction, covering the ground by a network of their branches, and thrusting an aerial branch or a tree in some favourable condition. We cannot record here the observations made by different authors to prove that the internal structure of the *Stigmaria* is the same as the structure of the roots, but only eliminate, by a common observation, the opinion that the Stigmariæ and their *leaves* were fleshy plants, somewhat like the *Cacti* of our time, or like some *Euphorbiæ*. That they were hard plants is established by this fact—that they are found sometimes preserved in their outline, and scarcely flattened, in circumstances where all other vegetable remains have been entirely flattened or destroyed; and also that they are the only ones of which the impressions are preserved in the coal: the same may be said of their rootlets, generally named leaves. And as the coal is sometimes a compound of their remains only, it is not possible to deny that their texture was essentially woody, like the texture of ferns. Of their relation to *Sigillaria* we will assert nothing; but we think that their relation is as near to *Lepidodendron* as to *Sigillaria*. We have seen some impressions of *Stigmaria* possessing the form of *Sigillaria*, but the transition was not very distinct. As the number of trees, especially of *Sigillaria*, is large, and there are a great many different species of them, we think that it would be right to admit many species of *Stigmaria*, instead of classifying them in two or three species with a quantity of varieties.

1. *Stigmaria ficoides*, Brongt.—Stems creeping, branches alternate, dichotomous; rootlets long and round; intervals between the scars smooth or plaited, ribbed or wrinkled. It is the most common plant found in the coal-basins of Pennsylvania, especially in the lower veins. It has been many times asserted that these *Stigmaria* are commonly found in the shale of the bottom of the veins, and that they are scarcely present in the shales of the roof. We have carefully examined the general position of these plants, and have found them evenly distributed in the whole extent of the coal-basin, but generally in greater abundance in the low beds of coal. Sometimes this abundance at a particular locality is astonishing, either at the roof or at the bottom of the seams—so much so, that there are no traces of any other vegetables; but this predominance is nowhere so general a fact that we can draw any conclusions as to their distribution. In the bottom and also in the roof shales of the Mammoth Vein at Minersville, they are so plentiful that they entirely cover the slates; but one finds them nearly as abundant on the roof of the South Salem Vein at Pottsville—a vein generally considered as the uppermost of the anthracite series. Perhaps it may be asked why we admit these plants as creeping ones. It is easy to answer. On all the large surfaces covered with *Stigmaria* that we have examined, we have seen them horizontally placed, though they had preserved their cylindrical form in many instances; and in such cases their rootlets were descending in the shale in every direction, varying from a very oblique position to a perpendicular one.

2. *Stigmaria anabathra*, Corda, *Beytr.*, Plate XXXVI., p. 14.—Stem thick, forking, creeping; intervals between the scars either plated-ribbed or stellate. A very variable species, if we adopt the diagnosis established on the internal structure of the wood, without taking into account its external character. But we think that these internal characters—viz. the thickness of the woody cylinder, and the breadth of the vessels—may belong to many species. Commonly found with the former.

3. *Stigmaria costata*, Lesq., Plate II., fig. 3.—Differs from the former by the nearly regular, strong, and elevated ribs which separate the rows of scars placed in regular order, resembling the spiral position of the scars of *Sigillaria*. Perhaps our specimen, found at Salem Vein, Pottsville, was broken from the base of a *Sigillaria*. Perhaps this species is *Stigmaria regularis*, Brongt. (*Prod.*, p. 88), a species mentioned but not yet described by this author.

4. *Stigmaria umbonata*, Lesq.—Differs from *Stigmaria ficoides* by the scars being at least twice as broad and elevated, and having a single ring at the border. It may be *Stigmaria tuberculosa*, Brongt. (*Prod.*, p. 88), an undescribed species.

5. *Stigmaria irregularis*, Lesq., Plate II., No. 4.—Stem deeply and narrowly ribbed; scars distant and scarce, oval, sometimes acute at both ends, sometimes round, placed without order. As we have only the small specimen figured here, found at the Gate Vein, Pottsville, it would have been perhaps as well to omit mentioning it. Its appearance is very peculiar, resembling a calamites, with the marks of rootlets, and so evidently a *Stigmaria*.

6. *Stigmaria radicans*, Lesq., Plate II., No. 2.—Stem about two inches broad, narrowly striate in its length; scars irregular, and irregularly placed; rootlets apparently round and attenuated at the base. The Salem Vein, Pottsville. Scarcely a true *Stigmaria*, looking much more like a root.

7. *Stigmaria minuta*, Lesq., Plate XVI., figs. 1, 2.—Stem thick; lower scars very small, and near each other, placed in a spiral line, round; the superior ones more distant, oval, pointed, or open in their inferior part; central scars elongated, like a deep narrow line dividing the general scars. Both specimens figured here belong to the same species, found in the Vespertine below Pottsville. We have followed the transitions between both forms—the first evidently a *Stigmaria*, the second one belonging to a *Sigillaria*, or perhaps to a *Lepidodendron*.

V. Sigillaria, Brongt., *Hist. des Veg. Foss.*, i. p. 422.—Stems large, tree-like, ordinarily marked with parallel or reticulated ribs; scars of the leaves placed spirally in the middle of those ribs; scars disciform, oblong, round, scarcely lanceolate crosswise, with the sides mostly angular, marked in the middle by the vascular scars, ordinarily placed by three or by two, but seldom single. M. Brongniart, taking into consideration the internal structure of the plants of this class, has admitted them as probably belonging to the phanerogamous dicotyledonous plants, and so has removed them far from the *Lepidodendra*. We cannot admit this opinion. The leaves of the *Sigillaria*, their position on the stem, and the scars left by them, have so great an affinity with those of the *Lepidodendron* that we cannot but conclude that these classes of plants are closely related to each other. We have no plants now living which can be compared with the *Sigillariæ*—the nearest ones are the *Lycopodiaceæ*—and so we think that their true place, far removed from the dicotyledonous plants, is between the *Lycopodiaceæ* and the ferns, differing from the former in the manner in which the leaves are attached to the stem, and from the ferns especially by the form of their long, linear, grass-like leaves. Like the *Lepidodendra*, these *Sigillariæ* bore their leaves on their young shoots, or on the summits of their branches, and the leaves falling, easily left small scars, which were enlarged as the trees were growing up. We have never seen as large trunks of *Sigillariæ* as those of *Lepidodendra;* nevertheless, there are many standing around Carbondale, and visible in the bed of the river, of which the diameter is from 8 inches to 1 foot.

1. *Sigillaria lepidodendrifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 426, t. 161.—Stem without ribs, undulate, transversely wrinkled below the scars, the wrinkles parallel to the base of the scars; scars nearly rhomboidal; lateral angles acute, the inferior and the superior rounded; vascular scars, three well marked, the medial one punctiform, the lateral ones linear, arched; leaves long, keeled, three-nerved, enlarged at the base. Seen at the Lehigh Summit. The scars, though nearly obliterated, are visible enough to indicate that our species is the same as M. Brongniart's. It has also the leaves attached to it.

2. *Sigillaria sculpta*, Lesq., Plate XIII., fig. 3.—Stem irregularly and narrowly striate in its length, without ribs; wrinkles undulate; scars elevated, smooth, quadrangular, rhomboidal oblique, emarginate cordate above, with the other angles acute; vascular scars three, the medial one oval, placed crosswise, the lateral ones linear, arched. A fine species, somewhat resembling the following, but differing by the elevated scars, emarginated above, and pointed below. In its corticated state the scars are square and ribbed, as figured in *α*. The Gate Vein, New Philadelphia.

3. *Sigillaria obliqua*, Brongt.—Surface of the stem undulate, striate, or scarcely ribbed, the ribs indicated by undulate lines; scars oblique, half round at the base, angular, trapeziform above; vascular scars three, oblong. We have found it at the same vein as the former, but very scarce.

4. *Sigillaria fissa*, Lesq., Plate XIII., fig. 4.—Surface undulate, marked in its length by narrow, undulate, smooth lines; scars distant, elevated, cordate, obtuse in outline, deeply emarginate above, round, obtuse below, with two acute angles at both sides, and a single oval vascular scar, attached in the middle of a semilunar or arched ring. A beautiful species, found at Muddy Creek.

5. *Sigillaria dilatata*, Lesq., Plate XIII., fig. 5.—Surface marked with thin, undulate, and smooth, very narrow lines; scars near each other, plane, enlarged on the sides, and nearly twice as broad as high; emarginate cordate above, very obtuse below, lateral angles very acute; vascular scars three, the medial one broadly oval crosswise, the lateral ones, linear, arched. In its corticated state it is narrowly undulated on the whole surface, with the lines only diverging above the vascular scars, which are oval, the two exterior lengthwise, the central one crosswise. Preserved in the collection of Carbondale.

6. *Sigillaria Schimperi*, Lesq., Plate XIV., fig. 1.—Surface undulated, narrowly plaited, and striate crosswise; scars slightly undulated, striate in the same direction, nearly round in outline; the upper marginal line well marked, and extending horizontally on both sides, the inferior one slightly marked, rounded; vascular scars two, oval, placed below an arched linear depression. Muddy Creek. A beautiful and remarkable species, dedicated to our friend Professor W. P. Schimper, the eminent European Bryologist, and author of the *Fossil Flora of the Red Sandstone of the Vosges.*

7. *Sigillaria stellata*, Lesq., Plate XIV., fig. 2.—Surface deeply marked with undulated branching lines or wrinkles, diverging in every direction from the scars and around them; scars nearly plane, hexagonal, the upper side obtusely emarginate, the under side obtuse, the others straight, equal; vascular scars three, the medial one semilunar, the lateral ones placed a little higher, oval, pointed downwards, and diverging to the sides. Large specimens of this beautiful species are preserved in the cabinet of Mr Clarkson, at Carbondale.

8. *Sigillaria Menardi*, Brongt., *Hist. des Veg. Foss.*, i. p. 430, t. 158, figs. 5, 6.—Stem mamillate, furrows distinct, reticulated, joined crosswise; scars close, nearly as large as the mamillæ, equal, nearly round, slightly enlarged, and obtuse on the sides, emarginate above; leaves very long, linear, keeled, many-nerved; nerves parallel, equal, thin, obsolete. Muddy Creek and Gate Vein, New Philadelphia. Common in the superior beds of the anthracite basins of Pennsylvania. Our species is evidently the same as the one described by M. Brongniart;

it differs only by the very narrow furrows between the scars; but this is only accidental. We have seen also specimens with broader furrows.

9. *Sigillaria Brardii*, Brongt., *Hist. des Veg. Foss.*, i. pp. 65, 431, t. 158, fig. 4.—Stem undulate, mamillate; mamillæ nearly plane; furrows obtuse, distinct, reticulated crosswise; surface corticated, smooth, decorticated, striate in its length; scars nearly round, smaller than the mamillæ, with the angles acute on the sides, emarginate above; vascular scars three, oblong, the medial one transversal. Gate Vein of New Philadelphia.

10. *Sigillaria Defrancii*, Brongt., *Hist. des Veg. Foss.*, i. p. 432, t. 159, fig. 1.—Stems mamillate; mamillæ transversely lanceolate; furrows deep, acute, reticulate, distinct, smooth; scars discoid, with the lateral angle acutely keeled; inferior margin slightly convex, superior very arched and slightly emarginate; vascular scars three, the medial one like a point, the lateral ones linear, arched. Muddy Creek—scarce.

11. *Sigillaria Serlii*, Brongt., *Hist. des Veg. Foss.*, i. p. 433, t. 158, fig. 9.—Stem mamillate, with the mamillæ elevated, nearly rhomboidal, broader transversely; furrows deep and distinct; scars placed in the upper part of the mamillæ, transversely lanceolate, with the lateral angles very acute, decurrent in the mamillæ; vascular scars three points. Seen in the Trevorton low coal. The specimen is not very distinct.

12. *Sigillaria tessellata*, Brongt., *Hist. des Veg. Foss.*, i. p. 436, t. 157, fig. 1, t. 162, figs. 1-4.—Surface marked with longitudinal undulated narrow ribs; scars discoid, as broad as the ribs, about square; hexagonal, with the sides obtuse, and slightly emarginate above. Trevorton coal; specimen indistinct. It has been sent to M. Brongniart from Wilkesbarre.

13. *Sigillaria elegans*, Brongt., *Hist. des Veg. Foss.*, i. p. 438, t. 146, fig. 1; t. 155 and 158, fig. 1.—Surface ribbed; ribs and furrows deeply marked, alternately enlarged and narrowed, and so undulated; ribs slightly mamillate; mamillæ nearly hexagonal, convex, laterally broader; scars discoid, near each other, and nearly as large as the mamillæ; vascular scars three, the lateral ones arched, the central linear, horizontal. Lehigh Summit, and also New Philadelphia.

14. *Sigillaria Brochantii*, Brongt., *Hist. des Veg. Foss.*, i. p. 442, t. 159, fig. 2.—Stems marked with deep undulated furrows, slightly mamillate, smooth; scars oblique, rhomboidal, transversely lanceolate, with the lateral angle very acute; superior and inferior ones arched, obtuse; vascular scar, a single central point. Found at Lehigh Summit; a broken but distinct specimen.

15. *Sigillaria alveolaria*, Brongt., *Hist. des Veg. Foss.*, i. p. 443, t. 162, fig. 5.—Stem ribbed; ribs equal, narrow; scars discoid, nearly contiguous, oval, without angles; vascular scars, three points placed in the upper part of the disc. Shamokin.

16. *Sigillaria scutellata*, Brongt., *Hist. des Veg. Foss.*, i. p. 455, t. 150, fig. 23, t. 163, fig. 3.—Stems ribbed; ribs convex, equal, or alternately contracted and enlarged at the scars; furrows deep, straight, or sinuous, distinct; scars discoid, round, oval, about as large as the ribs; longer than broad, slightly angular on the sides, and round, keeled at the base; vascular scars three, punctiform. Found at Muddy Creek,—a poor specimen.

17. *Sigillaria Sillimanni*, Brongt., *Hist. des Veg. Foss.*, i. p. 460, t. 147, fig. 1.—Stem ribbed; ribs alternately and slightly contracted and enlarged; transversely wrinkled above the scars, and obliquely below; scars discoid, twice as far from each other as their length, a little narrower than the ribs, oval, oblong, rounded on each side; vascular scars three—the medial one punctiform, the lateral ones linear, arched. A species described by M. Brongniart, on specimens sent from Wilkesbarre. We have not seen any specimens of it.

18. *Sigillaria oculata*, Brongt., *Hist. des Veg. Foss.*, i. p. 461.—Stem ribbed; ribs narrow, with straight distinct furrows; bark smooth; scars discoid, oval-rounded, emarginate above, more distant from each other than the diameter of the ribs; vascular scars, three—the medial one punctiform, the lateral ones oblong, arched. Found at Trevorton in its decorticated state, as figured by Sternberg (*Vers.* 1-3, p. 40, t. 31, fig. 1), and described under the name of *Syrigodendron complanatum.*

19. *Sigillaria polita*, Lesq., Plate XIV., fig. 3.—Stem ribbed; ribs nearly plane, very smooth, as broad as the distance between the scars; separated by narrow, deep, and very straight furrows; scars discoid, enlarged both sides, round above, the lower margin convex, with two lateral angles very obtuse; vascular scars three—the medial one transverse, linear, straight in the middle, and convex at both ends; the lateral ones linear, arched. This fine species from Carbondale has some affinity with both *Sigillaria Saullii*, Brongt., and *Sigillaria hyppocrepis*, Brongt., different from the first by its straight and larger ribs—from the second by the round base of the scars and the flattened ribs.

20. *Sigillaria dubia*, Lesq.—Stems ribbed; ribs well marked, narrow, half an inch broad, with the furrows obtuse, deeply marked; very narrowly striate or wrinkled in its length; scars about twice as distant from each other as they are long; obovate, with the lateral angles scarcely marked; vascular scars three, placed above—the medial one semilunar, with the horns turned upwards, and nearly converging; the lateral ones linear, straight, parallel; bark thick, striate. Trevorton low coal. It is very near *Sigillaria Cortes*, Brongt. (*Hist. des Veg. Foss.*, i. p. 167, t. 147, figs. 3, 4); differing only in the greater distance of the scars, being broader at the base, and by the wrinkles more deeply marked on the ribs. Perhaps a variety.

21. *Sigillaria obovata*, Lesq., Plate XIV., fig. 4.—Stem ribbed; ribs broad, a little more than one inch, nearly flat and smooth, or obsoletely striate; furrows deep and narrow; scars a little less distant from each other than the breadth of the ribs; obovate; inferior margin very obtuse; vascular scars three—the medial one linear, short;

the lateral ones linear, slightly arched. Trevorton Coal, low beds. This species is related to the former by the obovate form of the scars, evidently differing by its broad, flat, smooth ribs, and the form of the vascular scars. The bark is striated lengthwise, as in the former; but the scars on the bark are semilunar in this species, and squarish-oval in the former.

22. *Sigillaria reniformis*, Brongt., *Hist. des Veg. Foss.*, i. p. 470, t. 142.—Ribs very broad, flattened, scarcely striate in their length; scars reniform, rounded, a little broader than long, emarginate above; furrows faintly marked; bark thick; vascular scars of the decorticated stem geminate, oval, oblong. The Gate Vein at Pottsville and New Philadelphia; common in the superior beds of the anthracite basins, but always found in its decorticated state.

23. *Sigillaria lævigata*, Brongt., *Hist. des Veg. Foss.*, i. p. 471, t. 143.—Stem ribbed; ribs very broad, flattened, with deep acute furrows; bark thick, thinly striated, or wrinkled in its length; scars discoid, hexagonal, rounded, with the lateral angles obtuse; vascular scars three—the medial one very small, the lateral ones oval-lanceolate, larger. In the decorticated state, the vascular scars are geminate, contiguous, very large. New Philadelphia, Gate Vein; found only decorticated.

24. *Sigillaria elongata*, Brongt., *Hist. des Veg. Foss.*, i. p. 473, t. 145 and 146, fig. 2.—Stem ribbed; ribs straight, equal, with deep angular furrows; scars discoid, oblong, lanceolate; truncate at the base and at the summit, or slightly emarginate above; vascular scars three, placed above—the medial one very small, the lateral ones oblong; bark thick; decorticated stem deeply striate; scars oblong. Lehigh Summit; a specimen scarcely distinct.

25. *Sigillaria rugosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 476, t. 144, fig. 2.—Stem ribbed; ribs plane, equal; furrows straight, narrow, distinct; ribs marked, with very slender points in the middle, between the scars; scars discoid, oval, distant twice their length; vascular scars three, placed above—the medial one like a point, the lateral ones oblong, parallel. Sent to M. Brongniart from Wilkesbarre; known to us only by his description.

26. *Sigillaria alternans*, Lind. & Hutt., *Foss. Fl.*, i. p. 159, t. 6.—Stem ribbed; ribs broad, equal; scars two, approximate, elliptical, with a small vascular scar in the middle. Pittsburg Seam at Greensburg.

27. *Sigillaria catenulata*, Lind. & Hutt., *Foss. Fl.*, i. p. 159, t. 56.—Stem ribbed; ribs broad; scars elliptical, long, or lanceolate, acute at both ends, joined together by a continuous line without any vascular scar, except a point in the middle. Trevorton Low Coal. These two last species are evidently the decorticated state of species either already published with other names, or unknown in their perfect form.

28. *Sigillaria discoidea*, Lesq., Plate XIV., fig. 5.—Stems furrowed; furrows distant, irregular, deeply marked and wrinkled; distance between them large—two or three inches; flattened; irregularly dotted; scars discoid or round, elevated, half globular, diminishing in size, slightly emarginate below, very near each other, marked in the middle with a deep irregular point. We have given a true copy of this vegetable relic; we have it from a sandstone rock at Lehigh Summit. Its place in the family of the *Sigillariæ* is scarcely acceptable. But as we could not obtain any good specimens for further examination, we have nothing else to say about its other characters; we mention it here till some better opportunity to study it is afforded.

VI. Syrigodendron, Sternb. & Brongt.—Stems furrowed, ribs equal, parallel, covered with a bark ordinarily transformed into coal, bearing, on the exterior surface of the ribs, small scars which are not discoid, and have no impressions of vascular scars.

1. *Syrigodendron pachyderma*, Brongt., *Hist. des Veg. Foss.*, i. p. 479, t. 166, fig. 1.—Bark thick; ribs and furrows obtuse, distinct, striate on their external surface; wrinkles (striæ) arched, and converging to the scars, which are small, nearly square, bitoothed above: in the decorticated state the scars are linear and simple. Common at Trevorton Low Coal.

2. *Syrigodendron cyclostegium*, Brongt., *Hist. des Veg. Foss.*, i. pp. 480 and 166, figs. 2, 3.—Bark thin; ribs convex, with broad, obtuse, distinct furrows; striate; scars marked on an elevation of the ribs; nearly round, forming a small depressed circle. Same locality as the former. A large perpendicular wall of roof-slate at Trevorton is covered with the stems or bark of these *Syrigodendron*. (See Sketch.)

VII. Lepidodendron, Sternb.—Stems large, tree-like, sometimes as long as one hundred feet or longer; dichotomous, bearing leaves on the young branches or shoots; branches ordinarily fastigiate. Leaves linear, sometimes linear-lanceolate; bark covered with the scars left by the falling of the leaves at their point of attachment; oval-lanceolate or acute at both ends, marked on the middle or above it by a triangular or rhomboidal vascular impression, ordinarily transversely three-pointed; below the inferior angle of the vascular scar there are ordinarily two oval slightly diverging impressions which we name tubercles, and a medial line from the base of the vascular scar to the tail of the general scar; this line sometimes follows the direction of the scars, descending from one to the other, and nearly dividing them into two longitudinal parts. In this case it is ordinarily stopped above the vascular scar by a diverging furrow, forming a lid or a crown, either triangular or trapezoidal, above the vascular scars. We name the distance between the scars *a margin;* it is ordinarily a good character. It is truly astonishing to see how well these impressions of the scars of the *Lepidodendron* have been preserved. We have seen many specimens at Mr Clarkson's, and one also at Mr Moore's, of which the impressions were as distinct as if they had been carved in the stone by the best engraver. We have had good opportunity for studying the remarkable fossil-remains of this family in the cabinet of Mr Clarkson at Carbondale, where, during more than fifteen years, that gentleman has collected the largest and most beautiful specimens. The roof of the vein of coal worked at Carbondale, under the direction of Mr Clarkson, is almost entirely covered with impressions of trunks of *Lepidodendra*, sometimes of an immense size. There are some of them seventy feet long and about two feet broad, which are not at all narrowed at the upper end, where they are broken, and which consequently must have been much longer than the preserved part. The affinity of these trees with the *Lycopodiaceæ* of our time has been fully established by Mr Hooker from his observations on the internal structure of the fruits, the *Lepidostrobi*. But we know nothing about the mode of growth of these enormous vegetables, nor how they were sustained on the soft ground where they were living. We cannot assert anything satisfactory in this matter; but we think that for this genus, as for the *Sigillariæ*, the roots were nothing but the long creeping *Stigmariæ*, making by their ramification a true network to support the tree, and drawing, by their long and innumerable rootlets, the vegetable sap in sufficient abundance to promote the rapid growth of those trees bearing only small leaves at the upper part of their branches. We find in many *Lycopodiaceæ* the same disposition of roots and branches.

1. *Lepidodendron aculeatum*, Sternb., *Vers.*, i. p. 10, and 23, t. 6, fig. 2, and t. 8, fig. 1.—General scars oboval, elliptical, narrowed and acute at both ends; tail pointed and curved below; vascular scars obtuse, regularly rhomboidal; medial line deeply transversely short-wrinkled; tubercles oval. A variable species commonly found in the low beds of the coal-basins. Minersville, Lehigh Summit, Carbondale, &c.

2. *Lepidodendron rugosum*, Sternb., ii. p. 178, t. 68, fig. 4.—Scars oval, narrowed, acuminate at both ends; vascular scars trapezoidal, transversely marked with three points united by an elevated line; tubercles two, one of them sometimes obliterated; medial line furrowed broadly, transversely wrinkled. Carbondale and Zanesville, Ohio.

3. *Lepidodendron crenatum*, Sternb., *Vers.*, i. p. 10, figs. 20, 23, t. 8, fig. 2.—Scars elliptical, narrowly pointed at both ends, slightly curved below; vascular scars large, acute, rhomboidal, three-pointed; medial line transversely wrinkled in its inferior part only; transverse points, and turbercles obsolete. Found at Carbondale. In our specimens the vascular impression is acute at both sides.

4. *Lepidodendron obovatum*, Sternb., *Vers.*, i. p. 10, t. 6, fig. i. t. 8, fig. 1.—General scars obovate, pointed above, narrowed and acuminate below, vascular scars rhomboidal obtuse, with three somewhat obliterated points. Common in the low beds of the coal-basins.

5. *Lepidodendron modulatum*, Lesq., Plate XV., fig. 1.—Scars oval, narrowed acuminate at both ends, curved at the base, separated by a broad, half round, elevated, and deeply-wrinkled margin; wrinkles undulated, and parallel to the scars; vascular scars rhomboidal, obtuse arched above, narrowed at the base in a long point, acute at both sides, marked with three transverse points united by a depressed line; tubercles narrow; medial line deeply marked and transversely furrowed by deep short wrinkles; appendage double. A beautiful species preserved at Carbondale somewhat resembling *Lepidodendron rugosum.*

6. *Lepidodendron giganteum*, Lesq., Plate XV., fig. 2.—General scars oval, trapezoidal, elongated, acute both ends; vascular scars nearly in the middle; rhomboidal, quadrangular, with three points in the middle; appendages irregular, longer on one side; tubercles very small, short, oval; medial line marked from the summit to the lower end of the scars; smooth. Common at Carbondale, and found also at Lehigh Summit. This species may be the same as the *Lepidodendron undulatum*, Sternb., this being in a decorticated state.

7. *Lepidodendron vestitum*, Lesq., Plate XVI., fig. 3.—General scars oval, trapezoidal, acute at both ends, separated by an irregular smooth margin, covering the borders of the scars; vascular scars quadrangular, trapezoidal, placed at the summit of the general scars, with three points in the middle; no appendages; tubercles large, oval; medial line deep, smooth, curved. A peculiar and well-characterised species, found at Wilkesbarre. The margins of the scars are sometimes very broad, covering the borders of the scars, but detached from them like a frame, and easily broken and falling off.

8. *Lepidodendron conicum*, Lesq., Plate XV., fig. 3.—General scars oval, acute, and narrowed at both ends; vascular scars triangular, conical, with a single oval point in the middle, and two broad oval tubercles below; appendages none; medial line marked only by a row of long, undulate, transverse wrinkles; margins flat, broad, deeply wrinkled; wrinkles parallel to the scars, or marked in the same direction. Carbondale, where we have found many specimens. Though well marked and distinct, it may be a decorticated impression.

9. *Lepidodendron oculatum*, Lesq., Plate XVI., fig. 4.—Scars oval, acuminate at both ends; vascular scars marked only in the superior outline by a linear line, curved like a bow, and transversed by another narrow perpendicular line, at the base of which there are marked two large oval tubercles; medial line deeply wrinkled, obsolete; margin of the scars very broad (half an inch), flat, undulately wrinkled or striate. A beautiful species, perhaps the same as the following in its decorticated state. Preserved at Carbondale.

10. *Lepidodendron distans*, Lesq., Plate XVI., fig. 5.—Scars oval, lengthened, acute, or acuminate at both ends; vascular scars rhomboidal, square, transversely marked with three points; appendages two on each side; tubercles small, diverging; medial line deep, transversely cut by broad short wrinkles; margin between the scars very broad, striate, or wrinkled in their length with undulate smooth lines, flat; scars very smooth. Same place as the former.

11. *Lepidodendron rimosum*, Sternb., *Vers.*, vol. i. pp. 11, 21, 23, t. 10, fig. 1.—Scars distant, elliptical, acute at both ends; margins irregularly wrinkled in the length; vascular scars rhomboidal, concave, without points; medial line obsolete. Found at Trevorton. It is only a decorticated state of another species.

12. *Lepidodendron obtusum*, Lesq., Plate XVI., fig. 6.—Scars trapezoidal, acutely pointed above, slightly narrowed and abruptly obtuse below; vascular scars nearly placed in the middle, rhomboidal-obtuse above, acute below, angular on both sides, marked transversely with three points; appendage irregular, distinct on one side only; tubercles oval, diverging; medial line wrinkled; margins broad, undulately striate, and furrowed in their length. Collection of Carbondale.

13. *Lepidodendron carinatum*, Lesq., Plate XV., fig. 4.—Scars oval, hexagonal, angular, acute at both ends, with narrow, deep, keeled, smooth margins; vascular scars rhomboidal, obtuse above, triangular below; appendages short, obsolete; tubercles small, oval; medial line obsolete, transversely wrinkled. Found at Carbondale.

14. *Lepidodendron clypeatum*, Lesq., Plate XV., fig. 5, and XVI., fig. 7.—Scars irregularly trapezoidal, acute at both ends, obtuse on the sides, with narrow linear margins; vascular scars large, obtuse on the inferior and the superior borders, enlarged and acute on both sides, transversely three-pointed; appendages obsolete, descending to the very obsolete medial line, where they unite in an acute angle; tubercles obsolete on one side, well marked on the other; oval. Common at Carbondale. Plate XVI., fig. 7, represents the decorticated state of this species.

15. *Lepidodendron sigillarioides*, Lesq., Plate XV., fig. 6.—Scars exactly trapezoidal, with the acute angles at both ends; margins narrow, smooth; vascular scars dilated, acute at both ends, marked with three points; without any appendages, neither medial lines nor tubercles. Lehigh Summit.

16. *Lepidodendron Mieleckii*, Göpp., *Syst. Fil. Foss.*, p. 465, t. 44, figs. 1, 2. — Scars regularly rhomboidal, acute at both ends; vascular scars plain, with five nearly equal angles, the two inferior rounded. Lehigh Summit. Perhaps a decorticated state of another already-described species. At different places in the coal-basin of Pennsylvania, as at Minersville, Trevorton, Carbondale, and Johnstown, and always in the lowest vein, we have found also small branches of *Lepidodendron*, sometimes with the leaves, which we could easily relate to *Lepidodendron Sternbergii*, Brongt., *L. acerosum*, Lind., *L. dilatatum*, Lind., *L. selayinoides*, *L. elegans*, Brongt. But as the only reliable character for the distinction of these plants is the form of the scars, and their relative position, it is useless to describe such small branches or species of which the impressions are not distinct.

VIII. Ulodendron, Rhodes.— Stems simple (?), tree-like, covered with rhomboidal scars of the leaves; branches distechous, strobilaceous, covered with densely-imbricated leaves.

1. *Ulodendron majus*, Lind. and Hutt., *Foss. Flor.*, vol. i. p. 22, t. 5.—Scars of the branches distant, orbicular, eccentrically bossed; scars of the leaves transversely half rhomboidal, rounded on the inferior margin, superior angle acute, the lateral ones acuminate. The single specimen of this species which we have seen belongs to the Rev. Mr Brown of Charlestown, Kenawha, and was found in the lowest vein of coal there.

2. *Ulodendron Lindleyanum*, Sternb., *Vers.*, ii. p. 185, t. 45, fig. 4.—Scars of the branches very large and distant, oval, and eccentrically bossed; scars of the leaves marked only by obsolete points, placed in spiral. In the collection of Mr Clarkson at Carbondale there are two beautiful specimens of this species. The scars of the branches are about 5 inches long, and 3 inches broad. The eccentric lump, which is irregularly oval, and placed in the upper part of the scar, is surrounded by undulated radiating lines, terminating at the margin of the general scars.

FRUITS.

I. Lepidophyllum, Brongt.—Leaflets sessile, simple, entire, lanceolate or linear, one to three nerved. This description of M. Brongniart, copied by M. Unger in his *Gen. et Spec. Plantarum*, mentions only the blade of the fruit of a *Lepidodendron.* These fruits are attached together in catkins (*lepidostrobus*), formed of a scale, attached at a right angle to the axis by a short pedicle, inflated at the top, and supporting a spore-case (sporange) full of spores, and elongated above in a leaflet, the lanceolate or linear blade. These fruits or sporanges are imbricated around the axis: their position is well indicated by the cross section of a catkin in Plate XVII., fig. 1. We do not think the leaves of *Lepidodendron* worth mentioning and describing, these being much alike in all the species which we have been able to examine.

1. *Lepidophyllum acuminatum*, Lesq., Plate XVII., fig. 2.—Blade nearly 1 inch broad, slightly narrowed near the base, 3 inches long, acuminate, binerved. Johnstown, lowest bed of the coal. This species resembles *Lepidophyllum trinerve*, Lind. and Hutt., *Foss. Flor.*, vol. ii. p. 195, t. 152, but differs from it by its two nerves.

2. *Lepidophyllum obtusum*, Lesq., Plate XVII., fig. 3. — Blade three-fourths of an inch broad, more than 4 inches long, linear, abruptly terminated in a short point, marked in the middle by a broad, obsolete, inflated nerve. Same place as the former. We have seen many broken specimens of this species, which would lead us to suppose that it was about twice as long as here figured.

3. *Lepidophyllum lanceolatum*, Brongt., Lind., and Hutt., *Foss. Flor.*, vol. i. t. 7, figs. 3, 4.— Sporange inflated, irregularly five-angular, narrowed and obtuse at the base, enlarged above; blade lanceolate, pointed, entire, one-nerved. Our species is probably the same as that figured by Messrs Lindley and Hutton; but we have seen better specimens. The beautiful one figured, Plate XVII., fig. 1, belongs to Mr Chambers at Carbondale.

4. *Lepidophyllum affine*, Lesq., Plate XVII., fig. 5.—Differs from the former by its obtuse blade and its long pointed sporange. New Philadelphia; very scarce.

5. *Lepidophyllum hastatum*, Lesq., Plate XVII., fig. 7.—Sporange long-pointed, blade enlarged at the base in two diverging auricles; hastate slightly acute, with a strong nerve; sporange lanceolate, acute. Found by the Rev. Mr Moore near Greensburg.

6. *Lepidophyllum brevifolium*, Lesq., Plate XVII., fig. 6.—Sporange narrowed at the base in a long point; blade very short, enlarged at the slightly-obtuse sides. Common at Wilkesbarre Low Coal. In this species the angles of the blade are not diverging at the base, and the blade is much shorter than in the former species. We found it also abundantly in the lowest bed of coal at Johnstown and Wilkesbarre.

7. *Lepidophyllum plicatum*, Lesq., Plate XVII., fig. 4.—Blade linear, lanceolate, obtuse, narrowed at the base, curved (geniculated) in the middle; nerved from the base to half its length, the nerve disappearing. We have not seen the sporange of this species, of which we have a single specimen from the Gate Vein, Pottsville.

8. *Lepidophyllum lineari*, Brongt., is a leaf of *Lepidodendron;* linear, carinate, nerved with parallel nerves. We mention it only for its abundance at Wilkesbarre and Johnstown, in connection with *Lepidophyllum brevifolium.*

II. Lepidostrobus, Brongt.—Catkins cylindrical, composed of winged sporanges, attached to a common axis, and imbricated. It is impossible to give a satisfactory description of these *Lepidostrobi*, when they are found in their perfect or normal state, and when the form of the imbricated sporanges, and of the blade or wing, cannot be exactly ascertained. In the two places above mentioned—viz. at the low beds of coal at Wilkesbarre and at Johnstown—we have seen the three following forms described by Messrs Brongniart and Lindley; but certainly the separate sporanges of them, found together, and described above, were part of some of them.

1. *Lepidostrobus ornatus*, Lind. and Hutt., *Foss. Flor.*, vol. i. p. 163, t. 26.—Catkins cylindrical, about 1 inch broad, with a thick woody axis.

2. *Lepidostrobus variabilis*, Lind. and Hutt., *Foss. Flor.*, vol. i. t. 10, 11.—Catkins cylindrical or ova-lobtuse; scales acute, densely imbricated.

3. *Lepidostrobus pinaster*, Lind. and Hutt., *Foss. Flor.*, vol. iii. t. 198.—Catkins small, cylindrical, 2 inches long, scales rhomboidal.

III. Brachyphyllum, Brongt. (?)—Stem dichotomous; leaves imbricated, conical, obtuse, appressed, placed spirally around the stem.

1. *Brachyphyllum obtusum*, Lesq., Plate XVII., fig. 8.—We have classed under this name, and till it is better known, this remarkable branch, which ought to belong to this genus. The leaves or scales, which appear to be narrowed below, like the sporanges of the *Lepidophylla*, are rounded above, marked in the middle by an elevated line like a nerve. If this plant is a true *Brachyphyllum*, we cannot conceive why it has been generally taken for the branches of some coniferous tree. It looks much more like an elongated and narrow catkin of a *Lepidodendron*, viz. a *Lepidostrobus*, or is perhaps only a branch of some *Lepidodendron.* Our specimens of this plant were found at the South Salem Vein, Pottsville. Before leaving this remarkable class of plants—viz. the stems found in the coal-formation—we shall remark that we have never been able to find in this formation any specimens which would lead us to suppose that they were the fossil remains of dicotyledonous or phanerogamous plants. We have seen at Mr Lawton's of Barlow, near Marietta, Ohio, some specimens of petrified wood with concentric circles, which ought certainly to belong to some coniferous tree. But the geological age of the formation where this fossil wood occurs is far from being exactly ascertained. It is a coarse loose sandstone which reposes in the coal sandstone, but the direction of its beds is not in accordance with the direction of the sandstone below it. This at least is what has been affirmed by Mr Lawton. The bivalve shells found in this formation are also far different from the shells of the coal. Nevertheless, the presence of this formation, placed immediately above the coal sandstone, containing fossil trees of a description entirely different from those of the coal, is a remarkable coincidence. Though this formation is of small extent, and may be a comparatively new fresh-water formation, it merits a closer examination and attention from the geologists of Ohio. Its extent is about three miles long and one or two miles broad.

IV. Cardiocarpon, Brongt.—Capsules lenticular, compressed, obcordate or reniform, acuminate. These fruits and those of the following genus have been differently classed. As they have never been found attached to the branches, all that has been asserted about them, except their form, is hypothetical. We would not dare to express any opinion, as these fruits are very scarce in the anthracite basins of Pennsylvania, and as we have had scarcely an opportunity to examine their internal structure.

1. *Cardiocarpon Trevortoni*, Lesq.—Capsule plane, nearly orbicular, emarginate, cordiform above, pointed at the base, marked in the middle by a sharp elevated line, very smooth. Trevorton upper bed of coal, mixed with *Dyctiopteris obliqua.* It resembles *Cardiocarpon emarginatum*, Göpp. and Berg., *De Fruit*, p. 24, t. 3, fig. 35; but it is pointed at the base. Differs also from *Cardiocarpon latum* (Newberry, *Annals of Science*, p. 153) by its elevated medial line.

2. *Cardiocarpon plicatum*, Lesq., Plate XVII., fig. 9.—Differs from the former by its undulate plaited surface, without medial line. Found at the same locality.

3. *Cardiocarpon punctatum* (?), Göpp. and Berg., *De Fruit*, p. 24, t. 2, fig. 26.—Capsule plane, reniform or round, emarginate, marked with points regularly placed by five. Our specimen from Muddy Creek differs from this species by the surface being slightly concave, and the points irregularly placed.

V. Trigonocarpum, Brongt.—Fruit ovoid, three or six ribbed; ribs thickened at the base, three of them broader, with a broad hexagonal flattened top. We have scarcely found any good specimens of these fruits in the coal-basins of Pennsylvania, where all the fossil remains are ordinarily flattened in the shales; but they appear to be common in the coal sandstone of Ohio, and there are a great many of them preserved in the cabinets of Professor Newberry and of Dr Hildreth at Marietta. We can only indicate with certainty the following ones :—

1. *Trignocarpum Schulzianum*, Göpp. and Berg., *De Fruit*, t. 2, figs. 22, 23.—Fruit oblong, triangular, with the angles five-ribbed. Trevorton Low Coal.

2. *Trigonocarpum Hildreti*, Lesq.—Fruit oval-oblong, narrowly three-ribbed, with the intervals finely striate. From Ohio; preserved in the collection of Dr Hildreth.

3. *Trigonocarpum oblongum*, Lind. and Hutt., *Fos. Flor.*, iii. t. 193.—Fruit oval, pointed, slightly compressed, more than one inch long, and three quarters of an inch broad; marked with three large ribs; intervals smooth. A broken specimen from Trevorton.

VI. Rhabdocarpos, Göpp. and Berg.—Fruit oval or elliptical-oblong, marked in its length with parallel nerves or narrow ribs.

1. *Rhabdocarpos amigdalæformis*, Göpp. and Berg., *De Fruit et Sem.*, p. 21, t. 1, fig. 12.—Fruit oval, marked in the middle by a longitudinal elevated line. Trevorton Low Coal.

2. *Rhabdocarpos venosus*, Lesq.; *Carpolites venosus*, Sternb., *Vers.*, ii. p. 208, t. 58, figs. 16, 17.—Fruit oval, marked lengthwise by small undulated wrinkles. The Gate Vein, Pottsville. This species agrees well with the figure of Sternberg, but it is a true *Rhabdocarpos*.

VII. Carpolithes, Sternb.—This genus contains the fruits, very variable in form, of which the affinity is doubtful.

1. *Carpolithes fraxiniformis*, Göpp. and Berg., *De Fruit et Sem.*, p. 26, Plate III., figs. 33 and 34.—Fruit elliptical, linear, flattened, obtuse, nearly smooth. We have found in the Vespertine, below Pottsville, specimens of a fruit which resembles this one described by M. Göppert. It is not possible to tell anything about it. It looks like a flattened elongated sporange, full of small seeds.

2. *Carpolithes bifidus*, Lesq., Plate XVII., fig. 10.—Fruit apparently pedicellate, oval-oblong, arched; split in two parts above, three-ribbed near the base; pedicle (?) thick, ribbed. Gate Vein, New Philadelphia.

3. *Carpolithes disjunctus*, Lesq., Plate XVII., fig. 11.—Fruit oval, lanceolate, slightly obtuse, divided into two parts, the superior one convex, the inferior concave, diverging from the other. Found also at Trevorton. This remarkable specimen looks as if the oval fruit had been turned aside, or removed from its place (round the base as an axis), and left its impression on it. It is quite smooth.

4. *Carpolithes acuminatus*, Sternb. (?), *Vers.*, 4, t. 7, fig. 15.—Fruit small, about two lines long, one line broad, oval, lanceolate, convex, acute at one end, obtuse at the other, entirely smooth. We have found at Shamokin the species described above, which resembles Sternberg's figure. On the same slate with this fruit there are some other much smaller, scarcely half a line broad, round, flat, or varying much in size and in form. These fruits appear to have been externally of a hard texture, like the fruits of some Gramineæ or Cyperaceæ.

5. *Carpolithes platimarginatus*, Lesq., Plate XVII., fig. 12.—Fruit oval, acute, convex, smooth, broadly margined; margin flat, broader near the point, disappearing below. Trevorton Low Coal.

6. *Carpolithes bicuspidatus*, Sternb., *Vers.*, i. t. 7, fig. 8.—Fruit flattened, round, slightly pointed on one side, scarcely emarginate on the other, with a point on the emargination. Found at Muddy Creek, and at the Gate Vein of Pottsville. It looks like the fruit of a Calamite.

7. *Carpolithes multistriatus*, Sternb., *Vers.*, ii. p. 208, t. 39, figs. 1, 2.—Fruit broadly oval, large, pointed on one side, flattened on the other, marked in its length with equal ribs, separated by obtuse furrows; ribs about one line broad. Shamokin Vein, west of the village.

VIII. *Carpolithes umbonatus*, Sternb., i. tab. 9, fig. 2.—This is scarcely a fruit; it is very irregular in its outline, irregularly bossed and ribbed, and does not look at all like an organic relic, but more like a pebble of iron. It is commonly found in slates of the coal, varying in diameter from half an inch to about half a foot. To the description of the species mentioned above we will subjoin a short enumeration of the genera and species which, in our opinion, shall be eliminated, or of which the place will be changed. These are, *Cordaites, Poacites, Cyperites*, and *Pinnularia*.

I. Cordaites.—Leaves simple, sessile, placed spirally, half embracing the stems with very narrow parallel nerves.

1. *Cordaites borassifolia*, Ung.—Leaves simple, spathulate, entire, very long, nerves thin, parallel, epidermis formed of striate parallel cells, stomate, simple. These are long leaves or stems, of which many fragments were found in the upper beds of the anthracite coal, near Pottsville. Their place and their nature is undetermined. M. Brongniart has placed them near the *Næggerathia*, supposing them to be some dicotyledonous plant of the Gymnosperma.

2. *Poacites*, Brongt.—Leaves linear, long, with nerves equal and parallel. We have found many of these *Poacites* in the upper beds of the coal, in the same locality as the former; we think that they are the leaves of some *Sigillaria*.

3. *Cyperites*, Lind. and Hutt., *Hist. Foss. Flor.*, i. t. 43, figs. 1, 2.—Leaves linear, with two primary nerves on both

sides, and secondary ones between them. These are also found in the upper beds of the coal at Pottsville, at the Salem and Gate veins. They are also certainly the leaves of some *Sigillariæ*.

4. *Pinnularia*, Lind. and Hutt., *Foss. Flor.*, ii. tab. 3.—These vegetable remains are evidently roots. Though we think their description and nomenclature useless when their connection with the plants to which they belong is not ascertained, we have made a drawing of the most interesting of them. Preserving the nomenclature of this genus, as established by Messrs Lindley and Hutton, we would name those figured, as follows :—

1. *Pinnularia calamitarum*, Lesq., Plate I., fig. 9.
2. *Pinnularia pinnata*, Lesq., Plate XVII., fig. 18.
3. *Pinnularia fucoides*, Lesq., Plate XVII., fig. 19.
4. *Pinnularia horizontalis*, Lesq., Plate XVII., fig. 21.
5. *Pinnularia capillacea*, Lind. and Hutt., l. c., Plate XVII., fig. 22.
6. *Pinnularia confervoides*, Lesq., Plate XVII., fig. 20. The only one of which the name merits preservation, as its identity may be ascertained everywhere, is this last one.

The foregoing Essays by Mr Lesquereux are the results of researches made by him in the years 1852–1854, upon the fossil flora of Pennsylvania, under my direction, at the expense of the Commonwealth. I have been therefore much surprised and chagrined to find their publication partially forestalled by the production of a portion of the same matter in a *Report on the Fossils of the Western Kentucky Coal-Field*, recently issued as a part of the Geological Survey of that State. In a prefatory paragraph to that Report, Mr Lesquereux remarks, " As for the right I may have to quote a few lines of a Report delivered in 1854 to the Director of the Geological State Survey of Pennsylvania, I do not think that it can be denied me. This Report, elaborated with great care, and the arduous labour of two years, was to appear in the *Final Report of the Geological State Survey of Pennsylvania*, but it is a question if it will ever be published." In answer to this feeble attempt at an apology for a breach of literary obligation, I have merely to reply that the action of the Legislature to proceed with the publication of my work was notorious, and that Mr Lesquereux never wrote to me to know if my well-known wish to print had been disappointed.

Since the rendering in of his Report to me on the Fossil Plants of Pennsylvania in 1854, M. Lesquereux has read (February 1858) a catalogue of nearly all the Coal Plants of North America, including the Pennsylvanian ones, to the Pottsville Scientific Association, which that body has published. Embracing, as this does, many species and localities not mentioned in the foregoing Essay, the following synopsis of it, omitting many descriptive details, will, I trust, be acceptable to the palæontological reader.

CATALOGUE OF THE FOSSIL PLANTS WHICH HAVE BEEN NAMED OR DESCRIBED FROM THE COAL-MEASURES OF NORTH AMERICA.

By LEO LESQUEREUX.

FILICES OR FERN LEAVES.

NEUROPTERIDEÆ.

1.—Noeggerathia, Rut.

1. Noeggerathia *obliqua*, Göpp., old red sandstone (Ponent), Pottsville.
2. ——— *obtusa*, Lsqx., old red sandstone (Ponent), Lehigh, below Mauch Chunk.
3. ——— *minor*, Lsqx., same place.
4. ——— *Bockschiana*, Lsqx. (*Cyclopteris Bockschiana*, Göpp.), old red sandstone (Vespertine), opposite Mauch Chunk.
5. ——— *Beinertiana ?* Göpp., Cuyahoga falls (Newb'y).
6. ——— *microphylla*, Newb'y (ined.), Cuyahoga falls.

All the true *Noeggerathia* that I have seen belong to the old red sandstone. *N. Beinertiana ?* Göpp., mentioned with doubt by Dr Newberry, is rather a *Cordaites*, and I am still in doubt if *N. microphylla* truly belongs to this genus.

2.—Odontopteris, Brgt.

1. Odontopteris *squamosa*, Lsqx., Shamokin, low coal.
2. ——— *alata*, Lsqx.
3. ——— *Brardii*, Brgt. This species is stated by M. Unger as found at Mauch Chunk. It may be the true one; but I have some doubt about it. It has, perhaps, been mistaken for the former, which it resembles, differing evidently, nevertheless, by its more pointed leaflets, and by the absence of leaflets to the main rachis.
4. ——— *crenulata*, Brgt., Tremont, new vein.
5. ——— *Schlotheimii*, Brgt., same place.
6. ——— *dubia*, Lsqx. A small specimen, no locality mentioned.

7. ODONTOPTERIS *Neuropteroides*, Newb'y (ined.), Cuyahoga falls. The species of this genus appear to belong mostly to the low coal.

3.—DICTYOPTERIS, Gutb.

1. DICTYOPTERIS *obliqua*, Bunb'y. Trevorton, Sharp Mountain Vein, Pottsville, &c.—Salineville, O., Newb'y.

4.—CYCLOPTERIS, Brgt.

1. CYCLOPTERIS *flabellata*, Brgt., Tremont new vein.
2. *Whittleseya elegans*, Newb'y, Annals of Science of Cleveland, No. 10; found abundantly at Cuyahoga falls, O.—low coal.

5.—NEPHROPTERIS, Brgt.

1. NEPHROPTERIS *fimbriata*, Lsqx., Salem v., Pottsville; Pomroy, O.
2. ——— *laciniata*, Lsqx., Muddy Creek, Schuylkill Co.
3. ——— *elegans*, Lsqx., Shamokin.
4. ——— *undans*, Lsqx., Gate v., Middleport.
5. ——— *trichomanoides*, Brgt., Gate and Salem v., Pottsville; Pomroy, O.
6. ——— *hirsuta*, Lsqx., common, especially in the upper coal.
7. ——— *orbicularis*, Brgt., Room-run mines, near Mauch Chunk.
8. ——— *Germari*, Göpp., Salem v., Pottsville.

6.—NEUROPTERIS, Brgt.

1. NEUROPTERIS *speciosa*, Lsqx., Gate v., Port Carbon.
2. ——— *hirsuta*, Lsqx., through the whole extent of the Coal-measures, mostly in the upper coal.
3. ——— *Clarksoni*, Lsqx., Ferris v., near Archibald and Eagle Hill, above Bellmont (grey-ash coal).
4. ——— *fissa*, Lsqx., Gate v., Pottsville.
5. ——— *smilacifolia*, Sternb., Shamokin.
6. ——— *plicata*, Sternb., Salem v., Pottsville.
7. ——— *flexuosa*, Brgt. The most common of all, found through the whole extent of the Coal-measures.
8. ——— *Loschii*, Brgt., Gate and Salem v., Pottsville. It descends to the low coal, and is perhaps only a variety of the former.
9. ——— *rotundifolia*, Brgt., Gate v., &c., with both the former.
10. ——— *tenuifolia*, Brgt., Shamokin.
11. ——— *gigantea*, Brgt., Zanesville, O.
12. ——— *Grangeri*, Brgt., Gate v., Port Carbon.
13. ——— *Cistii*, Brgt., same place.
14. ——— *delicatula*, Lsqx., Sharp Mount v., Pottsville.
15. ——— *Villersii*, Brgt., Gate v., Pottsville; Pomroy, O.
16. ——— *gibbosa*, Lsqx., Salem v., Pottsville.
17. ——— *undans*, Lsqx., Gate v., Middleport.
18. ——— *crenulata*, Brgt., Salem v., Pottsville and Tamaqua.
19. ——— *tenuinervis*, Lsqx., Gate v., Pottsville.
20. ——— *dentata*, Lsqx., Salem v., Pottsville.
21. ——— *Desorii*, Lsqx., West Wood (upper coal).
22. ——— *heterophylla*, Brgt., common. Upper Coal-measures.
23. ——— *minor*, Lsqx., Tamaqua.
24. ——— *rarinervis*, Bunb'y, Room Run mines, near Mauch Chunk.
25. NEUROPTERIS *Moorii*, Lsqx., Greensburg coal, higher than the Pittsburg bed.
26. ——— *adiantites*, Lsqx., locality unknown.
27. ——— *lancifera*, Newb'y (ined.), Cuyahoga falls.

SPHENOPTERIDEÆ.

1.—SPHENOPTERIS.

1. SPHENOPTERIS *Davalliana*, Göpp., ? lowest coal, Kenawha Salines, Va.
2. ——— *tenella*, Brgt., ? Gate v., Port Carbon (a poor specimen).
3. ——— *Gravenhorstii*, Brgt., Black Mine, Westwood.
4. ——— *Dubuissonis*, Brgt., Gate v., Port Carbon.
5. ——— *abbreviata*, Lsqx., same place.
6. ——— *intermedia*, Lsqx., Black Mine, Westwood.
7. ——— *flagellaris*, Lsqx., Sharp Mt. v., Pottsville.
8. ——— *plicata*, Lsqx., New Philadelphia (upper coal).
9. ——— *latifolia*, Brgt., low coal, Pennsylvania and Ohio.
10. ——— *acuta*, Brgt., low coal Kenawha, Salines (in the cabinet of Marietta College).
11. ——— *obtusiloba*, Brgt., Cuyahoga falls, Newb'y.
12. ——— *glandulosa*, Lsqx., Shamokin (low coal).
13. ——— *decipiens*, Lsqx., Salem v., Young's Landing, Pottsville.
14. ——— *polyphylla*, Lind. & Hutt., low coal, Iowa and Kentucky (in D. D. Owen's cabinet).
15. ——— *Newberrii*, Lsqx., Wilkesbarre, low coal.
16. ——— *Lesquereuxii*, Newb'y (ined.) Cuyahoga falls.
17. ——— *squamosa*, Lsqx., probably low coal. Locality unknown.
18. ——— *artemisæfolia*, Brgt. Locality unknown.
19. ——— *parvifolia*, Newb'y (ined.), Cuyahoga falls.
20. ——— *concinna*, Newb'y (ined.), same place.
21. ——— *uncinnate*, Newb'y (ined.), same place.
22. ——— *Kirtlandiana*, Newb'y (ined.), Poland, O.
23. ——— *simplex*, Newb'y (ined.), Poland, O.
24. ——— *subspinosa*, Newb'y (ined.), Cuyahoga falls.
25. ——— *tenuis*, Newb'y (ined.), same place.
26. ——— *foliosa*, Newb'y (ined.), same place.
27. ——— *coriacea*, Newb'y (ined.), Salineville.

2.—HYMENOPHYLLITES, Göpp.

1. HYMENOPHYLLITES *furcatus*, Göpp. (Vespertine), Mauch Chunk and Pottsville. Lowest coal, Cuyahago falls, Newb'y.
2. ——— *Hildreti*, Lsqx., Great Kenawha, Salines, low coal.
3. ——— *capillaris*, Lsqx., same place.
4. ——— *fimbriatus*, Lsqx., Salem v., Pottsville; Pomroy, O.
5. ——— *affinis*, Lsqx., Gate v., New Philadelphia.
6. ——— *hirsutus*, Lsqx., Gate v., Westwood.
7. ——— *laceratus*, Lsqx., Johnstown, Penn., low coal.
8. ——— *giganteus*, Lsqx. (*Shizopteris lactuca*, Sternb. Gate v., north of Port Carbon.

PECOPTERIDEÆ.

1.—ASPLENITES, Göpp.

Fruit-dots linear, attached to the back of the secondary nerves; secondary nerves simple or dichotomous; frond bi-tripinnate.

1. ASPLENITES *rubra*, Lsqx., barren measures, Marietta, O.

2.—Alethopteris, Sternb. and Göpp.

Frond bi-tripinnatifid; secondary nerve nearly perpendicular to the medial nerve, either simple or forking.

1. Alethopteris *lonchitidis*, Sternb. This species is truly characteristic of the lowest coal, or that above the conglomerate, from the Mississippi to the anthracite basins of Pennsylvania.
2. ——— *Pennsylvanica*, Lsqx., Salem v., Pottsville.
3. ——— *Aquilina*, Göpp. Locality uncertain.
4. ——— *urophylla*, Göpp., Gate v., Pottsville.
5. ——— *Serlii*, Göpp., Room Run mines, near Mauch Chunk; Zanesville, O.; Kenawha, Salines, Va.
6. ——— *marginata*, Göpp., Tremont (new vein).
7. ——— *distans*, Lsqx., Muddy Creek, Schuylkill County.
8. ——— *obscura*, Lsqx., Gate v., Pottsville.
9. ——— *serrula*, Lsqx., Gate v., north of Port Carbon.
10. ——— *nervosa*, Göpp., Shamokin, Carbondale. Cuyahoga falls, Newb'y.
11. ——— *lævis*, Lsqx., Shamokin.
12. Alethopteris *rugosa*, Lsqx., Salem v., Pottsville.
13. ——— *muricata*, Göpp., Sharp Mt. v., Pottsville.
14. ——— *grandifolia*, Newb'y (ined.), Cuyahoga falls.
15. ——— *gracilis*, Newb'y (ined.), Cuyahoga falls.

3.—Callipteris, Brgt.

Frond bipinnatifid; pinnæ long, decurrent on the common rachis; pinnules continuous, slightly oblique, united, and decurrent at the base; medial nerve oblique, arched; secondary nerves oblique, arched, and bifurcate.

1. Callipteris *Sullivantii*, Lsqx. Found only at Shamokin.

4.—Pecopteris, Brgt.

1. Pecopteris *Cistii*, Brgt., Wilkesbarre (from M. Brongniart's indication).
2. ——— *polymorpha*, Brgt., common, upper coal.
3. ——— *distans*, Lsqx., with the former.
4. ——— *velutina*, Lsqx., Johnstown, Pa., low coal.
5. ——— *orata*, Brgt., Tremont (new vein).
6. ——— *Sheaferi*, Lsqx. It was found in M'Kean County.
7. Pecopteris *notata*, Lsqx., Salem v., Port Carbon, &c.
8. ——— *oreopteridis*, Brgt., Gate and Salem v., Pottsville.
9. ——— *pusilla*, Lsqx., same place.
10. ——— *arborescens*, Brgt., common in the upper coal, Pa. and Ohio.
11. ——— *dubia*, Lsqx., Gate v., Pottsville.
12. ——— *cyathæa*, Brgt., Gate v., Port Carbon.
13. ——— *arguta*, Brgt., upper Coal-measures. Pottsville and Pomroy, O.
14. ——— *abbreviata*, Brgt., Trevorton.
15. ——— *unita*, Brgt., Sharp Mt. v., Pottsville.
16. ——— *concinna*, Lsqx., Gate v., Pottsville.
17. ——— *pennæformis*, Brgt., Trevorton (new vein).
18. ——— *plumosa*, Brgt., Cuyahoga falls (Dr Newb'y).
19. ——— *Sillimani*, Brgt., Zanesville, O., following M. Brongniart, to whom it was sent.
20. ——— *Loschii*, Brgt., Sam. Ferris v., four miles W. of Archibald.
21. ——— *incompleta*, Lsqx., Gate v., Pottsville.
22. Pecopteris *elliptica*, Bunb'y, Zanesville, O. (Dr Newb'y).
23. ——— *inflata*, Newb'y (ined.), Cuyahoga falls, low coal.
24. ——— *pavifolia*, Newb'y (ined.), same place.
25. ——— *latirachis*, Newb'y (ined.), same place.

This genus truly characterises, by most of its species, the upper Coal-measures. I have never yet seen a true *Pecopteris* either in or below the conglomerates.

LEAVES OF DOUBTFUL AFFINITY.

1.—Crematopteris, W. P. Schp.

Frond simple, pinnate; rachis broad; pinnules vertical or oblique, oval-oblong, entire; nerve obsolete.

1. Crematopteris *Pennsylvanica*, Lsqx., Greensburg, Pa. (in Rev. Mr Moore's cabinet).

2.—Scolopendrites, Lsqx.

Frond simple, linear-lanceolate, large, deeply, irregularly toothed; medial nerve very slender; secondary nerves thin, pinnately forking, very oblique, distant.

1. Scolopendrites *grosse-dentata*, Lsqx., New Philadelphia (upper coal).

3.—Shizopteris, Brgt.

Frond irregular, pinnately lobate with the lobes elongated, dentate, diversely cut; primary nerves none; secondary nerves parallel, very thin.

1. Shizopteris *robusta*, Newb'y, (ined.), Cuyahoga falls, O.

4.—Cannophyllites, Brgt.

Leaves simple, entire, with a strong central nerve; secondary nerve oblique, simple, parallel, equal.

1.—Cannophyllites *cordata*, Newb'y, (ined.), Cuyahoga falls, O.

5.—Cordaites, Ung.

Stems erect, annulate by the persistent base of the leaves. Leaves simple, half embracing the stem, long, linear, one or two inches broad; nerves thin, parallel.

1. Cordaites *borassifolia*, Ung., abounds in the upper coal, Pa. & O.

ASTEROPHYLLITEÆ.

This family of plants is composed of herbaceous plants or of trees, of which the stems are ordinarily striated lengthwise, the branches and stems bearing whorls of leaves at the more or less distant articulations. The following genera, till some of them are better known, may be admitted in it, viz. *Sphenophyllum*, *Annularia*, *Asterophyllites*, and *Calamites*. The genus *Wolkmannia*, admitted by some authors, was formed for the nomenclature of the fruit of *Asterophyllites*; it cannot be separated.

1.—Sphenophyllum, Brgt.

Stems articulated, branching from the articulations; leaves wedge-shaped, verticillate by six to twelve, truncate at the top, either bi-lobate, or dentate, or laciniate.

1. Sphenophyllum *Schlotheimii*, Brgt., Salem and Gate v., &c., upper coal, Pa., and Ohio, Pomroy, O.

2. SPHENOPHYLLUM *emarginatum*, Brgt., same places.
3. ——— *filicaule*, Lsqx., same places.
4. ——— *trifoliatum*, Lsqx., Salem v., Pottsville.
5. ——— *oblongifolium*, Ung. ?
6. ——— *erosum*, Lind. & Hutt., Cuyahoga falls, (Newb'y).
7. ——— *peltatum*, Newb'y (ined.), same place.
8. ——— *laciniatum*, Newb'y (ined.), no locality mentioned.
9. ——— *brevifolium*, Newb'y (ined.), Cuyahoga falls, O.

The species of this genus, as well as those of the whole family, are pretty well distributed through the whole extent of the Coal-measures. A few species only appear to characterise a peculiar geological level.

2.—ANNULARIA, Sternb.

Like the former, but differs by the branches opposite from below the base of the verticillate leaves; leaves lanceolate or linear, nerved in the middle.

1. ANNULARIA *minuta*, Brgt., Gate v., Pottsville.
2. ——— *fertilis*, Sternb., upper Coal-measures. Common.
3. ——— *longifolia*, Brgt., Gate v., Pottsville, &c. It descends to the lowest coal.
4. ——— *sphenophylloides*, Ung., ? upper coal, Salem v., Gate v., &c., Pottsville; Pomroy, O.

These species are mostly found in the upper Coal-measures.

3.—ASTEROPHYLLITES, Brongt.

Stems articulated with opposite branches; leaves verticillate, numerous, equal, linear, acute, slightly joined together at the base. Inflorescence diœcious. Male flowers united in leafy catkins at the top of the branches (*Wolkmannia.*) The fruit is a small nutlet at the axil of the leaves.

1. ASTEROPHYLLITES *gracilis*, Brongt., Zanesville, O.
2. ——— *equisetiformis*, Brongt. Abounds in the upper coal.
3. ——— *foliosa*, Lind. & Hutt., same place.
4. ——— *crassicaulis*, Lsqx., Gate v., New Philadelphia.
5. ——— *ovalis*, Lsqx., same place.
6. ——— *sublævis*, Lsqx., Gate v., Westwood.
7. ——— *tuberculata*, Brgt., New Philadelphia, &c., upper coal.
8. ——— *lanceolata*, Lsqx., same place.
9. ——— *aperta*, Lsqx., same place.

These three last species would belong to the genus *Wolkmannia*, Sternb. All the *Asterophyllites* belong to the upper Coal-measures, and scarcely descend to the low coal.

4.—CALAMITES, Suck.

Stems cylindrical, hollow, striated in the length, articulated in the leaves, narrow, encircling the stem like a sheet; ramification from the axil of the leaves.

1. CALAMITES *decoratus*, Brongt., Sharp Mt. v., Pottsville. This species appears to belong only to the upper coal.
2. ——— *Suckowii*, Brgt., common.
3. ——— *ramosus*, Brgt., Gate, Lewis, and Salem v., Pottsville, Cuyahoga falls, Newb'y.
4. ——— *undulatus*, Brgt., Sharp Mt. v., Pottsville. Cuyahoga falls, O., Newb'y.
5. ——— *cruciatus*, Sternb., same places as No. 3.
6. ——— *Cistii*, Brgt., Wilkesbarre and Carbondale, (low coal).
7. CALAMITES *dubius*, Artis., Gate v., Pottsville.
8. ——— *cannæformis*, Brgt., Carbondale, &c.
9. ——— *pachyderma*, Brgt., conglomerate sandstone, Trevorton; Akron, O., Newb'y. Also in the conglomerate.
10. ——— *nodusus*, Schloth., conglomerate, Cuyahoga falls, Newb'y.
11. ——— *bistriatus*, Lsqx., New Philadelphia (upper coal).
12. ——— *disjunctus*, Lsqx., Gate v., Pottsville.
13. ——— *approximatus*, Brongt., common.
14. ——— *Voltzii*, Brgt. Quoted by Dr Newberry without indication of locality.

STEMS OF TREES.

In this division of the stems, with the genus *Psaronius*, we have the following genera: *Caulopteris*, *Diplothegium*, *Stigmaria*, *Sigillaria*, *Syrigodendron*, *Lepidodendron*, *Lepidophloios*, *Ulodendron*, *Megaphytum*, and *Knorria*.

1.—CAULOPTERIS, Lind. & Hutt.

Stem thick, externally marked with scars left by the insertion of the petioles. Scars large, oval, with a broad, double, or simple margin; disposed in spirals around the stem.

1. CAULOPTERIS *punctata*, Lsqx. Locality unknown.
2. ——— *gigas*, Lsqx., Carbondale (Mr Clarkson's cabinet).

?3. ——— *Cistii*, Brgt., Wilkesbarre (quoted by M. Brongniart).

Specimens of this genus are very scarce. The few of which the locality was ascertained, belong to the low coal.

2.—DIPLOTEGIUM, Corda.

Stem round, equal, marked with elevated scars, very near each other, and placed in spirals; the top of the elevated scars being abruptly cut, rhomboidally.

1. DIPLOTEGIUM *Brownianum*, Corda., Portage Summit, Pa., low coal.

3.—STIGMARIA, Brongt.

Stems creeping, from 2 to 6 inches thick, dichotomous, covered with leaf-like fleshy appendages, either simple or forking, long, contracted at the base, with a single vascular fascicle. Scars round, with a double ring and a small elevated point (*mamilla*) in the middle.

1. STIGMARIA, *ficoides*, Brgt. Everywhere from the base to the top of the Coal-measures. In the low coal it abounds, especially in the shales of the roof; elsewhere in those of the bottoms of the coal-beds.
2. ——— *anabathra*, Corda. Scarce.
3. ——— *costata*, Lsqx. Locality unknown.
4. ——— *unbonata*, Lsqx., Gate v., Pottsville.
5. ——— *irregularis*, Lsqx. Same place.
6. ——— *minuta*, Lsqx., old red sandstone (Ponent), Pottsville.
7. ——— *radicans*, Lsqx., Salem v., Pottsville.

All the species of *Stigmaria* have apparently the same range of distribution as No. 1.

4.—Sigillaria, Brongt.

Stems large, ribbed, mostly marked with parallel or reticulated furrows. Scars of the leaves placed in spirals, in the middle of the ribs, disciform, oblong, or round, with the sides mostly angular, marked in their middle by the scars of the vessels by three, two, seldom single.

1. Sigillaria *lepidodendrifolia*, Brgt., New Philadelphia, upper coal.
2. ——— *sculpta*, Lsqx. Same place.
3. ——— *obliqua*, Brgt., Salem v., Pottsville.
4. ——— *dilatata*, Lsqx., Gate and Salem v., Pottsville.
5. ——— *fissa*, Gate v., New Philadelphia.
6. ——— *Schimperi*, Lsqx., Muddy Creek.
?7. ——— *stellata*, Lsqx., Carbondale (Mr Clarkson's cabinet).
8. ——— *Menardi*, Brgt., Muddy Creek. A common species.
9. ——— *Brardii*, Brgt., New Philadelphia.
10. ——— *Defrancii*, Brgt., Muddy Creek, Pa., and Massillon, O., low coal.
11. ——— *Serlii*, Brgt. ? Trevorton, low coal.
12. ——— *tessellato*, Brgt., same place.
13. ——— *elegans*, Brgt., Summit, Lehigh, Carbondale, &c.—Cuyahoga falls, Newb'y, low coal.
14. ——— *Brochantii*, Brgt., Summit, Lehigh, low coal.
15. ——— *alveolaris* Brgt., same place, low coal.
16. ——— *scutellata*, Brgt., Muddy Creek.
17. ——— *Sillimanni*, Brgt., Wilkesbarre (quoted by M. Brongniart—no specimen seen).
18. ——— *oculata*, Brgt., Trevorton.
19. ——— *polita*, Lsqx., Carbondale (Mr Clarkson's cabinet).
20. ——— *obovata*, Lsqx., Trevorton, low coal.
21. ——— *reniformis*, Brgt. A common species.
22. ——— *lævigata*, Brgt., New Philadelphia, Gate v.
23. ——— *Yardleyi*, Sp. nov.
24. ——— *elongata*, Brgt., Summit, Lehigh.
25. ——— *attenuata*, Sp. nov.
26. ——— *alternans*, Lind. & Hutt., Trevorton, low coal.
27. ——— *catenulata*, Lind. & Hutt., same place.
28. ——— *discoidea*, Lsqx., Summit, Lehigh, low coal.
29. ——— *acuminata*, Newb'y, *Ann. of Science*, p. 164, fig. 1, Cuyahoga falls.
30. ——— *Biercei*, Newb'y, loc. cit., fig. 2, Coshocton, O.
31. ——— *pulchra*, Newb'y, loc. cit., fig. 3, Youngstown, O.
32. ——— *dentata*, Newb'y, loc. cit., fig. 4, Cuyahoga falls, O.
33. ——— *marineria*, Hildreth, Cuyahoga falls and Poland, O.
34. ——— *grandis*, Newb'y (ined.), Cuyahoga falls.
35. ——— *centralis*, Newb'y (ined.), Cuyahoga falls.
36. ——— *minuta*, Newb'y (ined.), Cuyahoga falls.
37. ——— *squamosa*, Newb'y (ined.), Cuyahoga falls.

5.—Syrigodendron, Sternb.

Stems furrowed; ribs equal, parallel, narrow, bearing on the corticated surface of the ribs small round scars, without any vascular marks. The stems belonging to this genus are mostly found ribbed, without any traces of scars.

1. Syrigodendron *pachyderma*, Brgt., low coal. Common.
2. ——— *cyclostegium*, Brgt., same places as the former.
3. ——— *Americanum*, Newb'y (ined.) Cuyahoga falls.

The geological distribution of both the former genera is not yet sufficiently examined. Some of the enumerated species are certainly identical with others. The *Sigillariæ* appear, like the *Stigmariæ*, to have lived during the whole epoch of the coal-formation; but it is not now possible to assert what species belong to a peculiar station.

6.—Lepidodendron, Sternb.

1. Lepidodendron *aculeatum*, Sternb., common, Carbondale, &c.
2. ——— *rugosum*, Sternb., Carbondale, &c., low coal.
3. ——— *crenatum*, Sternb., Lehigh Summit, &c.
4. ——— *obovatum*, Sternb. Common.
5. ——— *modulatum*, Lsqx., Carbondale.
6. ——— *giganteum*, Lsqx., Carbondale.
7. ——— *vestitum*, Lsqx., Wilkesbarre and Carbondale.
8. ——— *conicum*, Lsqx., Carbondale.
9. ——— *oculatum*, Lsqx., Carbondale (Mr Clarkson's cabinet).
10. ——— *distans*, Lsqx., same place.
11. ——— *obtusum*, Lsqx., same place.
12. ——— *carinatum*, Lsqx., same place.
13. ——— *clypeatum*, Lsqx. Common, Archibald, &c.
14. ——— *sigillarioides*, Lsqx., Lehigh Summit.
15. ——— *rimosum*, Sternb., Carbondale.
16. ——— *Mieleckii*, Göpp.,? Lehigh Summit.
17. ——— *elegans*, Brgt., Cuyahoga falls (Newb'y).
18. ——— *gracile*, Brgt., Cuyahoga falls (Newb'y).

All the species of this genus, and of the four following, belong to the low coal. It is very difficult to find a trace of *Lepidodendron* in the grey-ash coal of Pa., and I have never seen any species of this genus above.

7.—Lepidopholios, Sternb.

Stem tree-like, marked by the base of the leaves, which are persistent and forming scales; scars at the top of the scales.

1. Lepidopholios *laricinum*, Sternb., Cuyahoga falls, (Newb'y).
2. ——— *crassicaule*, Brgt., same place (Newb'y).

Fine specimens of *Lepidopholios* have been found in the shales of the low coal in Illinois, Iowa, and Virginia: they are still undescribed. Specimens of this genus, and of the three following, are very scarce.

8.—Ulodendron, Rhode.

Stems marked with the rhomboidal scars of the leaves, bearing two-ranked coniferous branches covered with imbricate leaves.

1. Ulodendron *majus*, Lind. & Hutt., Great Kenawha, Va.; Salineville, O. (Newb'y).
2. ——— *Lindleyonum*, Sternb., Carbondale (Mr Clarkson's cabinet).

9.—Megaphytum, Artis.

Stem tree-like without bark, bearing small point-like scars placed spirally with some larger two-ranked and obicular.

1. Megaphytum *discretum*, Newb'y (ined.), Cuyahoga falls.

10.—Knorria, Sternb.

Stems tree-like, covered with thick short leaves and scars of branches. Leaves round, sessile, disposed in spirals; scars of the branches round.

?1. Knorria *taxina*, Lind. & Hutt., Cuyahoga falls (Newb'y).
2. ——— *Hildrethii*, Newb'y; *Ficoidites scabrosus*, Hild., *Amer. Jour. of Science*, vol. xxxi. p. 31.
3. ——— *distans*, Newb'y (ined.), Summit Co., O.

CONES OR CATKINS AND THEIR SCALES.

1.—Lepidophyllum, Brongt.

Leaflets simple, sessile, entire, lanceolate, or linear, bearing at their base an inflated bag (sporange,) full of spores, and forming, by their union on a common axis, a catkin. *Lepidostrobus*.)

1. Lepidophyllum *acuminatum*, Lsqx., Johnstown, Pa.
2. ——— *obtusum*, Lsqx. Locality unknown.
3. ——— *lanceolatum*, Brgt., Carbondale (Mr Chambers' cabinet).
4. ——— *affine*, Lsqx., Wilkesbarre.
5. ——— *hastatum*, Lsqx., Greensburg, (Rev. Mr Moore's cabinet.)
6. ——— *brevifolium*, Lsqx., Wilkesbarre.
7. ——— *plicatum*, Lsqx., Wilkesbarre.

2.—Lepidostrobus, Brongt.

Catkin formed by winged sporanges (*Lepidophylla*), perpendicularly attached on a common axis, and imbricated.

1. ——— Lepidostrobus *ornatus*, Lind. & Hutt., Pa. and Ohio, low coal.

?2. ——— *variabilis*, Lind. & Hutt. With the former.
3. ——— *pinaster*, Lind. & Hutt., same places.
4. ——— *macrolepis*, Newb'y (ined.), Cuyahoga falls.

These two genera, being fruits of *Lepidodendron*, have of course the same geological distribution. The leaves of *Lepidodendron*, which are narrowly linear, grass-like, have been sometimes described either as blades of grass or as true *Lepidophyllum*.

3.—Brachyphyllum, Brongt.

Stems? or dichotomous axis covered with imbricated obtuse leaves placed in spirals.

1. Brachyphyllum? *obtusum*, Lsqx., low coal, Massillon, O.

FRUITS OR NUTLETS.

1.—Cardiocarpon, Brongt.

Capsules lenticular, compressed, obcordate or reniform, acuminate.

1. Cardiocarpon *Trevortoni*, Lsqx., Trevorton, low coal.
2. ——— *plicatum*, Lsqx. Same place.
3. ——— *Samaræforme* (Newb'y), *Annals of Science*, p. 152, fig. 1. Cuyahoga falls.
4. ——— *annulatum*, Newb'y, loc. cit., fig. 2. Youngstown, O.
5. ——— *latum*, Newb'y, loc. cit., fig. 3. Cuyahoga falls.
6. ——— *minus*, Newb'y, loc. cit., fig. 4. Same place.
7. Cardiocarpon *orbiculare*, Newb'y, loc. cit., fig. 5. Same place.
8. ——— *elongatum* (Newb'y), loc. cit., fig. 6. Youngstown, O.
9. ——— *punctatum*? Göpp., Muddy Creek.

All the species enumerated above, except perhaps the last, have been found in the low coal.

2.—Rhabdocarpos, Göpp. & Berg.

Fruit oval, ribbed in its length by parallel lines.

1. Rhabdocarpos *amygdalæformis*, Göpp. & Berg. Trevorton.
2. ——— *venosus*, Lsqx., Gate. v., Pottsville.
3. ——— *compressus*, Newb'y (ined.), Cuyahoga falls.

3.—Trigonocarpon, Brongt.

Fruit ovoid, three to six ribbed, with a broad hexagonal, flattened base.

1. Trigonocarpon *Schultzianum*, Göpp., Berg. Trevorton low coal.
2. ——— *Hilrethii*, Lsqx., Poland Co., O. (D. Hildreth).
3. ——— *oblongum*, Lind. & Hutt., Trevorton.
4. ——— *Nœggerathii*? Brgt. Cuyahoga falls (Newb'y).
5. ——— *tricuspidatum* Newb'y (ined.), same place.
6. ——— *magnum*, Newb'y, (ined.) Coshocton, O.
7. ——— *multistriatum*, Newb'y (ined.), Cuyahoga falls.

These fruits, and those of the following genus, have been mostly found in the low coal; a few of them are found in the upper Coal-measures, but always scarce.

4.—Carpolithes, Sternb.

Fruits or nutlets of variable forms.

1. Carpolithes *fraxiniformis*, Göpp., old red sandstone, (Ponent), below Pottsville.
2. ——— *bifidus*, Lsqx., Trevorton low coal.
3. ——— *disjunctus*, Lsqx., same place.
4. ——— *platimarginatus*, Lsqx., Trevorton.
5. ——— *acuminatus*, Sternb., same place.
6. ——— *bicuspidatus*, Sternb., common, low coal.
7. ——— *multistriatus*, Sternb., common. It ascends higher in the Coal-measures than the former.
8. ——— *umbonatus*, Sternb. Low coal.
9. ——— *retusus*, Sternb., Cuyahoga falls (Newb'y).
10. ——— *minutus*, Newb'y (ined.), same place.

To this enumeration of the species of fossil plants of our Coal-measures, I could add species of *Cyperites*, Lind. & Hutt., and of *Pinnularia* of the same authors. But the first genus represents only the leaves of some *Sigillariæ*. *Lepidodendron*, or even *Stigmaria*, and the species of the second, are referable to some roots which cannot be described by themselves.

About three hundred species of plants are enumerated in this catalogue. It is not possible to foretell how far the number may be increased by subsequent investigation. But until now the fossil plants of America have not been carefully collected, except by Dr Newberry and by myself; and it is probable that future explorations will at least double the number of these species. There are already about fifty species newly collected, which have not been described, and are not enumerated above.

My friend Prof. J. H. Balfour, Regius Professor of Botany in the University of Edinburgh, has kindly favoured me with the following notes upon the specimens of fossil vegetation figured on Plates XXI., XXII., and XXIII., and upon two other specimens not figured :—

As regards the fossil plants sent for examination, it is not easy to come to any definite conclusion regarding them; I can only, I fear, give very crude conjectures respecting their nature. We may call many of them Algoids, and refer to existing Algæ which they resemble, but it is absolutely impossible to point to any characters which will fix what they are. In speaking of the difficulty of determining such fossil specimens, Professor Harvey says—"I need but remind you of the algoid forms of *Podostemaceæ*—where you have often an external habit so closely resembling that of an alga, that, till you resort to the knife and the microscope, you may be easily deceived." Entertaining similar views, it is with great diffidence that I hazard any conjecture on the drawings sent for my inspection.

No. I. *Filicoid?*—A fern-like frond apparently resembling the primordial or barren frond of a Platycerium. The frond spreads in a radiating manner, with forked striæ not unlike the veins of a fern. At the edge the frond seems to have been folded in one or two places. There are several known species of Platycerium at the present day; viz., *Platycerium alcicorne*, a native of Madagascar and Eastern Asia, and found also in Eastern Peru; *P. grande*, in New Holland and Singapore; *P. stemmaria*, in tropical Western Africa; *P. biforme*, in the Malay islands.

The fossil plant, however, may be an algoid, although the forked venation is adverse to that view. If so, then it may be regarded as allied to Padina.

No. II. *Lepidodendron*, sp.?—A slender species of the genus, with imperfect markings in the form of dots arranged in a circular manner round the stem. The markings want the usual alternate arrangement of Lepidodendron scales.

No. III. *Leaf of a Gymnosperm?*—Resembling that of *Salisburi adiantifolia.* There appears to be a common broad petiole, whence proceeds a lamina divided into cuneate segments. The venation is very marked, and proceeds in a radiating manner.

No. IV. *Algoid?*—Resembling a Desmarestia. The stalk divides in a forked manner, and gives off narrow pinnæ, some of which are again pinnate.

No. V. *Algoid?*—Resembling *Nemastoma comosa*, an Australian alga. There is a central rachis which gives off branches, and then divides into small ramifications, which come off in a pinnate manner.

No. VI. *Algoid?*—Resembling *Halosaccion ramentaceum* of J. Agardh's work, the *Fucus ramentaceus* of Turner's "Icones Fucorum," vol. iii., tab. 149. In some of the fossil specimens there is a swelling whence the stalk seems to proceed.

On the whole subject of such fossil forms, I would take leave to forward to you the following words of Harvey, who, in speaking of a sea-weed called *Ptilota rhodocallis*, says:—"At first sight this beautiful species might almost be taken for *Phacelocarpus Billardieri*, so similar are its ramifications and colour; but the structure of the frond and the fructification are so different, that we are forced to refer these Algæ to widely-separated families. Geologists sometimes complain that botanists refuse definitively to name fossil plants whose impressions are left on sandstone, and, in the geological sense, *well-preserved;* but cases such as the present—and it is one of a thousand—show how uncertain must be the *determination* even of the best stone-printing of a fossil stem. What shall we say, then, of the positive settlement of the affinities and structure of fossil shadows, where there does not remain the faintest trace in stone of the entity that was and is not?"—J. H. Balfour.

The annexed Cuts, excluded for want of room from page 896, illustrate the different degrees of dip of the Levant Grey Sandstone on the Pennsylvania and New Jersey sides of the Delaware River, indicating a transverse fracture. (See page 896.)

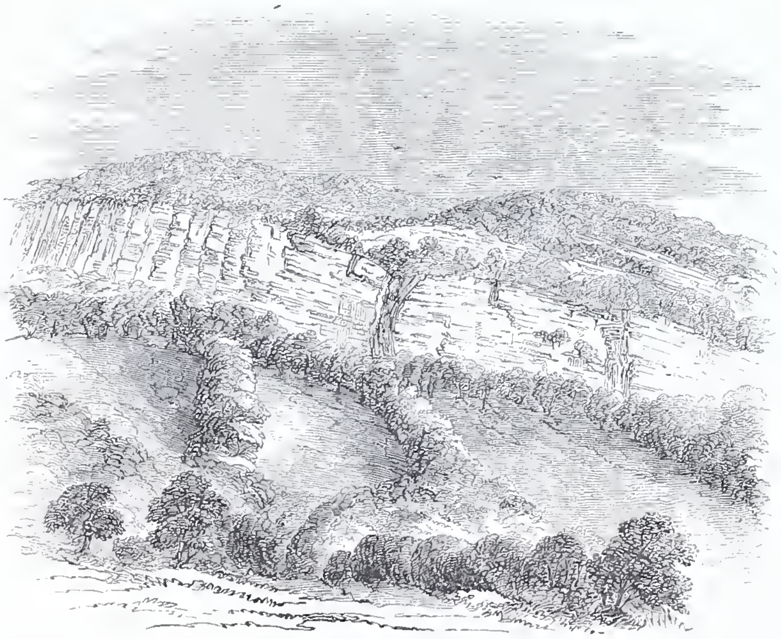


Fig. 700.—Kittatinny Mountain on the W. side of the Delaware Water-Gap.

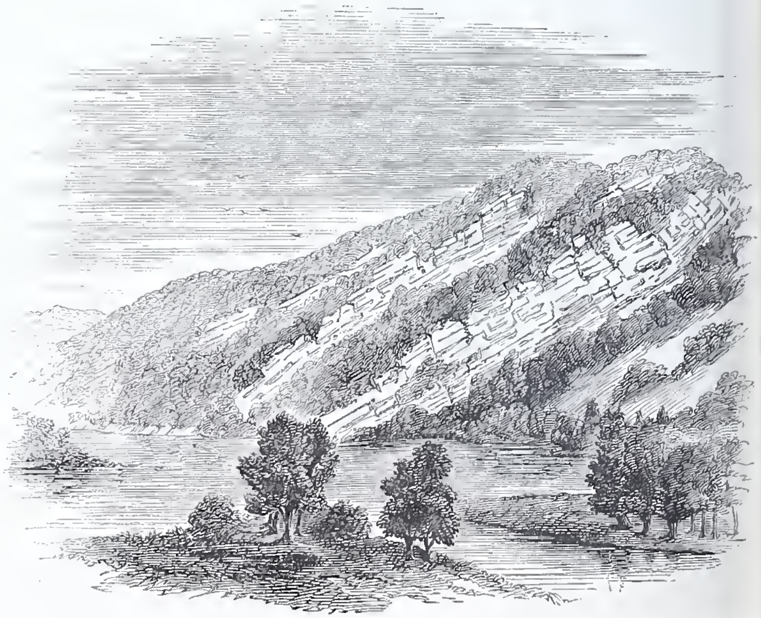


Fig. 700 *a*.—Kittatinny Mountain on the E. side of the Delaware Water-Gap.

ON THE LAWS OF STRUCTURE OF THE MORE DISTURBED ZONES OF THE EARTH'S CRUST.

Having several years ago, in the course of a prolonged investigation of the geological structure of the Appalachian chain of the United States, conducted partly in co-operation with Professor W. B. Rogers, as a purely scientific inquiry, partly by myself, in connection with the Geological Survey of Pennsylvania, discovered what we deemed important laws, applicable generally to all corrugated tracts of strata, I am prepared, by observations since made in the United States and in Europe, to extend their application, and give them a more general expression.

WAVE-LIKE FORM OF ALL UPRAISED TRACTS OF THE CRUST.

The first or most general fact to be enunciated respecting any portion of the earth's crust that has suffered elevation or depression from the position or level at which its strata were originally deposited, is, that the displaced beds present invariably the form of one or many waves, even when, within limited geographical areas, they may seem to retain an approximate horizontality. This comprehensive statement respecting the wave-like structure of the earth's crust is not invalidated by the instances of disordered dip seen in certain dislocated regions, such as some of the coal-fields of Great Britain ; for it will generally be found that the breaks or faults in the strata only separate disarranged portions of what were originally continuous undulations.

In all large stratified areas, where the dip is both gentle and persistent in its direction throughout considerable spaces, and where this dip is genuine—the result, that is to say, of a true displacement of the mass, and not a consequence of the original obliquity of deposition called false bedding—the crust-waves will be found to be of an amplitude proportioned to their flatness ; but in those districts where the prevailing inclinations are steep, and where they are directed to opposite points, it will be found invariably that the inclined masses are but the parts of successive arches or waves, the denuded or broken crests of which approach each other the closer as the dips are steeper.

EXEMPLIFIED IN PENNSYLVANIA AND IN THE UNITED STATES GENERALLY.

This cardinal fact of undulation in the structure of the earth's crust is admirably exemplified in the Palæozoic Basin of the United States, especially along its S. border, the Appalachian chain, and nowhere, perhaps, so well as in Pennsylvania. It is only necessary to appeal to any geological map and general section of the strata between the Atlantic and the Rocky Mountains—such, for example, as the Author has contributed to *Johnston's Physical Atlas*—to prove that every tract of inclined or dipping strata is but a segment of a great wave or waves of wider or narrower amplitude, and of gentler or steeper curvature. Even in those broad tracts of the central basin of the continent, where the strata, to a careless eye, seem to be absolutely horizontal, they possess an appreciable dip, which, continuously traced, changes its angle, and reverses its direction, until it discloses a very broad low wave. One such gentle yet majestic swell of the rocks extends from Lake Erie to Alabama, and fills the wide interval occupied by Ohio, Indiana, Middle Kentucky, and Middle Tennessee, between the great Appalachian coal-field and that of Illinois. Another divides the Illinois coal-field from that of Iowa and Missouri ; and similar flat undulations, on a scale of the grandest amplitude, heave the apparently level strata throughout the vast horizontal planes and steppes of Texas, Kansas, and Nebraska. For numerous and most striking instances of this law of wave-structure in districts of steeply-inclined strata, we need look no farther than the mountains of Pennsylvania, where, among the older rocks, almost every dipping mass is but a part of one or other flank of a more or less compressed high-crested wave, and where every gradation of form, from the most contracted to the most dilated, is discernible, as well in the N.E. half of the chain, within and round its coal-fields, as in the S.W., amid its alternating smooth valleys and steep rocky ridges. A mere glance at any of the numerous sections, general or local, which accompany this work, will suffice to show that undulation is the prevailing law in all the uplifted or displaced deposits.

PARALLELISM OF THE CRUST-UNDULATIONS.

It is another general fact connected with the disturbed zones of the crust, that where the displacement from horizontality has been great, the strata are arranged in longitudinal tracts, or great belts of parallel waves. These, where their symmetry of structure is not marred by dislocations of the strata, or hid by overlapping superficial deposits, exhibit a remarkable and beautiful resemblance to those great and continuous billows which are called by seamen rollers, and by mechanicians *waves of translation*. Far more continuous in their crests, more strictly parallel, and more symmetrical in form than the wind-produced waves upon the waters of the globe, such great swells or rolling billows, engendered by wholly different forces, are, I conceive, the true archetypes of the undulations visible in the more corrugated portions of the earth's crust. Perhaps in no uplifted district of the surface are these crust-waves so symmetrically developed, or so readily recognised, as in the Appalachian Mountains of the United States. It was there that Professor William B. Rogers and myself, analysing their forms, and tracing and connecting their axes, detected those phenomena of shape and gradation which led us to the general laws of crust-flexures which we have ventured to publish.

This parallelism of both the greater and lesser waves of the strata is conspicuous in every part of the Appalachian chain of Pennsylvania, but nowhere perhaps so obviously as in the region S.W. of the Susquehanna. There it must be discernible even to the passing traveller in the succession of the visible archings of the rocks, and in the extraordinary symmetry of the topographical features of the country resulting from it. Even without the aid of a Geological Map, we cannot fail to notice it in the beautiful parallelism of the long, slender, and gently-curving valleys, and the narrow, continuous, and extremely level mountain-crests. It is not less perceptible both within and exterior to the anthracite basins farther to the N.E., where indeed the law applies to flexures of all dimensions, down to those of very insignificant breadth. The amplest evidence of its universality is contained in the Geological Maps and sections illustrative of this descriptive text.

But we believe that generally all mountain zones, and all corrugated districts, which have been elevated, like the Appalachians, at one epoch, and by crust-movements observing only one prevailing direction, will be found to possess this wave-like structure, under similar conditions of gradation, and in a like conspicuous manner. It is only those tracts which have been revisited several times by the elevating and undulating forces, and especially those where the successive disturbances have not coincided in direction, but have crossed each other, causing interference and intersection of the waves, as in what is called a chopped sea—such districts, for example, as the Swiss Alps and the mountains of Cumberland and Wales—that we fail readily to discern the wave-structure of the strata, or, perceiving it in part, are unable, without extreme toil and patience, to connect the originally-related outcrops of the rocks, and reconstruct in our minds, and represent to the eye, the undulations that actually exist in a broken and disguised condition.

Wherever we have been led, either from observations in the field, or from a careful perusal of the descriptions of geologists, to a clear recognition of the dip-structure of any corrugated zone, whether mountain-chain or otherwise, not confused by different systems of elevatory movements of the crust, we have become impressed with its marked resemblance in all the essential features of the undulations, both as respects the typical forms of the individual waves, and the grouping and gradation of the several sets of waves, to the flexures characteristic of the Appalachian chain of America. I was particularly convinced of this resemblance upon examining, in the summer of 1848, the structure of the Jura chain of Switzerland;* and scarcely less struck with the agreement I noticed between the phenomena on the borders of the Alps, especially in the Bernese Oberland, and the features which distinguish the most corrugated tracts at the S.E. base of the chain of the Appalachians.

RELATIONS OF FLEXURES TO EACH OTHER.

If we regard now the flexures which constitute any great undulated or corrugated belt of strata, we shall find that these display the following laws or general facts of relationship:—

Parallelism.—1. When seen in their simplicity, or undisguised by cross breaks and undulations, those of a particular district show a remarkable degree of mutual parallelism. Not only are they parallel to each other, but to the general trend of the portion of the mountain system to which they belong, and especially to its chief igneous axes, where it possesses such.

This primary fact of parallelism of the anticlinal and synclinal undulations of a district to the general trend of its chief igneous axes, whether the waves be curved or straight, is finely illustrated in the structure of Pennsylvania. The mountain chain of the State is divisible lengthwise into four segments—a N.E. curving convexly towards the Atlantic slope; a central, very nearly straight: a S.W., sweeping convexly from the Atlantic slope, or towards the N.W.; and a S., almost absolutely straight, passing through Maryland into Virginia. Opposite the N.E. segment stands the similarly-curving chain of the highlands of New York and New Jersey; opposite the straight middle group of waves, the equally straight and strictly parallel, deep, synclinal flexure of the Montgomery and Chester Valley; opposite the curving portion of the district of the Juniata, the curving flexures of the metamorphic district of York County, and the S. mountains of Cumberland and Adams; and opposite the straight S. zone, the straight metamorphic range of the Blue Ridge of Maryland.

Parallelism of Groups.—2. The flexures or waves, where the undulated zones are wide and complex, occur in groups or lesser belts, those constituting such subordinate series observing the law of parallelism still more strictly than group does towards group. This remarkable parallelism of the adjacent flexures in an undulated region belongs not only to those waves and groups of waves which are rectilinear in their crests, but to such as curve even very considerably in their lineation. Nowhere, perhaps, is the constancy of this law so well displayed as in the Appalachians. This great mountain-zone of the United States and Canada, about 1500 miles in length, and more than 150 in its maximum breadth, consists longitudinally of eleven different sections, *six* of which are straight, *three* curvilinear, and convex towards the N.W., and *two* also curvilinear, but convex towards the S.E. Three of the straight sections have an approximately E. and W. trend, and the other three an approximately N. and S. course. Notwithstanding the great windings in the direction of the chain thus indicated, it is remarkable that each division or segment of it, whether straight or curved, is made up of crust-waves and groups of waves, which are essentially in mutual parallelism; and wherever a seeming exception to this rule presents itself, as on the Upper Juniata in Pennsylvania, and in Northern Vermont, it will be found to arise from the interference or interlocking of the ends of the waves of different but adjacent segments.

Each of the natural divisions of the undulated zone of the State offers numerous interesting instances of the above-mentioned parallelism of the different groups of waves with each other. One of the most obvious and curious is that furnished by the several sets of flexures terminating W. near the river Schuylkill. First we have in the semi-igneous belt of the South Mountains a succession of closely-packed anticlinal and synclinal waves, terminating like the toes of the human foot, each more Northern one a little behind or E. of its S. neighbour. Parallel with this group of flexures, and just opposite to it towards the N.W., is a strikingly similar series, ranging from the Lehigh S. of the Kittatinny Mountain, and then through that ridge into the Orwigsburg Valley, ending in a series of spurs receding, like the others, in the manner of the human toes. Thirdly, there occurs to the N. of these still another group of waves, parallel to the two former, ranging from E. of the Lehigh through Mahoning and Sharp mountains into the Pottsville coal-basin; and, finally, a fourth belt coming out from Nesquehoning Mountain, traversing Locust Valley, and entering Broad Mountain, the E. synclinal spurs of which it disposes in precisely the same order; the anticlinal flexures separating these spurs being mutually parallel, and forming a group parallel to the three other groups.

This grouping of the individual waves in sets, and the reciprocal parallelism of the several sets compared together, is remarkably distinct in that part of the Geological Map which pictures the country W. of the Susquehanna. We there find between the Kittatinny or Cumberland Valley and Bald Eagle Valley, at the base of Alleghany Mountain, a succession of six groups of principal undulations, corresponding to the six anticlinal coves dividing the W. ends of the coal-basins E. of the river, and these six sets of waves, all gently crescent-shaped, are singularly parallel. Each group, excepting the N.W. one, which is simple, is composed of two or more main anticlinals, and in some instances of several subordinate flexures, like secondary waves undulating the slopes of primary ones, and these lesser ones are themselves disposed in groups, and yet all of these again are strikingly parallel.

Flexures of different Orders.—3. Crossing any great belt of anticlinal and synclinal flexures, such as that of the

---

* See Abstract of Communication to American Association for Advancement of Science, Cambridge, Mass., March 1849, p. 113.

Appalachians, or that of Belgium and the Rhenish Provinces, it will be noticed, when the undulations are carefully traced and compared, that they consist of more than one class as respects dimensions; indeed, they will be found to be of two or three grades, when grouped according to their length, height, and amplitude. In most parts of the Appalachian chain there are at least two prevailing magnitudes in the waves. The chief class, or primary undulations, are of great size, their length amounting to from 50 to 120 miles, and their breadth to several miles, except where they are closely compressed. The subordinate or secondary waves are seldom more than a fourth of a mile wide, nor do they usually exceed 10 miles in length, and in many groups they are much shorter. Frequently a third class is to be met with, of still smaller and less persistent flexures,—rolls of the strata, as they are called in the coal-mining districts of Pennsylvania,—which seem to be only local corrugations of the more superficial rocks, and not true undulations of the crust pervading the entire thickness of the formations. The relations of the primary to the secondary waves will be enlarged upon hereafter; it will suffice, under the present head of parallelism of flexures, to state that, for the Appalachians at least, those of the second order are not necessarily parallel to those of the first, though within a given district they observe among themselves the same mutual parallelism which the larger or primary waves exhibit.

In no part of the chain is this independence of direction of the lesser or secondary undulations towards the primary or chief flexures more conspicuous than in the three principal Anthracite basins of Pennsylvania. There the secondary waves of the strata, parallel individually, and parallel group with group, are yet not parallel with the chief synclinal axes of the troughs they occupy. Indeed, some of the longer ones range obliquely across the coal-basins, starting in the mountain-barrier of one side, and expiring far out in the Coal-measures towards the other, meeting and passing others coming towards them from the opposite direction. They would seem to be, in fact, symmetrical parallel warpings of only the more superficial pliable strata, compressed by the synclinal bendings of the crust which formed the primary basins. In the Wyoming Valley, or N. anthracite coal-field, this relationship of these smaller waves or saddles is especially manifest, for in consequence of the crescent-like form of this trough they come off into the middle of the basin from its S.E. barrier, at larger and larger angles, as we advance Northward.

FORMS OF THE WAVES.

Symmetrical Flexures.—The individual waves or flexures of a belt of undulated strata occur under three essential varieties of form. The first, or most simple, is that of a convex or concave wave, or, in technical geological language, an anticlinal or synclinal flexure, in which the two slopes of the wave are equal in their degree of incurvation or steepness.—(Fig. 701). This symmetrical form is restricted chiefly to the gentler or flatter undulations, and especially to those of considerable amplitude. We do occasionally meet with steep waves of the strata, having a nearly equal inclination on both their sides; but these are generally broken curves, exhibiting a snap or sudden angle at the anticlinal or synclinal axis, in place of the gradual arching, which is the normal form of all regular crust-undulations.

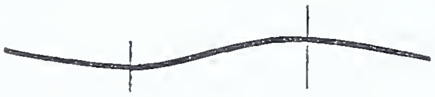


FIG. 701.—Symmetrical Flexure.

Undulations of the symmetrical type present themselves in Western and Northern Pennsylvania on a very grand scale. Two great groups of these may be recognised beyond the Alleghany Mountain: one enters the State from the N.E., and subdivides the N. bituminous coal-field into six successive basins; five very broad, depressed anticlinal waves penetrating S.W. into the high table-land covered by the Coal-measures. The erosive action of water has denuded the upper firmer strata from off the anticlinal or convex portions of these waves, and cut the district into as many parallel valleys, leaving intervening synclinal spurs. The inclination of the strata upon the opposite slopes of these broad waves is upon the average nearly the same in both directions—in some cases being steepest towards the S.E., in others towards the N.W., but, with one or two exceptions, always at a low angle. The other, or S.W. group of waves, nearly as wide and somewhat more prominent than the above mentioned, is composed of four parallel, equidistant, very straight undulations, traversing parts of Cambria, Indiana, Somerset, and Fayette counties. The anticlinal flexures are those of Negro Mountain, Laurel Hill, Chestnut Ridge, and the upheaved belt W. of Greensburg. In each of these there is an approximation to equality in the inclinations of the two flanks of the waves; though in each instance partaking somewhat of the character of the steeper flexures of the mountain-chain to the S.E., the N.W. slope is somewhat greater than the S.E. All these N.E. and S.W. undulations possess a width of several miles, and it may be noticed that their breadth enlarges, while their curvature or steepness lessens, progressively as we cross them in a N.W. direction. These facts, and an explanation of their cause, will be dwelt upon in another place.

Normal Flexures.—Another and more prevailing form displays an excess of incurvation, or steepness of flexure, on one side compared with the other. Waves of this type have been called *Normal Flexures* by my brother and myself in our descriptions of the Appalachian chain, where they are very common. They are to be seen abundantly in the Jura, and in the exterior hills of the Alps. They abound, too, in the undulated Palæozoic region of Southern Belgium, and are a marked feature in the coal-basins of that country.*

---

* See DUMONT'S "Mémoire sur les Terrains Ardennais et Rhenen," &c.

These flexures prevail wherever the forces that disturbed the crust were neither excessively intense nor very feeble. They usually hold an intermediate position geographically between the groups of flat symmetrical waves and those which are closely folded, answering to the middle place they occupy as respects energy of undulation. Almost invariably, those of a simply undulated tract exhibit their steeper slopes directed all to one quarter. The exceptions to this law will be instanced in another place, and their existence accounted for.

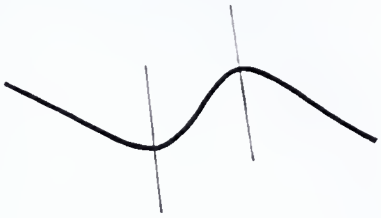


Fig. 702.—Normal Flexure.

Numerous beautiful examples of flexures of the normal type are to be met with singly and in groups throughout every section of the Appalachian chain of Pennsylvania, from the River Lehigh to Maryland. It is, indeed, the characteristic form of the flexures everywhere between the Kittatinny or main Appalachian Valley and the Alleghany Mountain. It distinguishes not only those larger waves which separate the coal-containing strata E. of the Susquehanna into special basins, but the minor undulations which throw the coal-measures of these basins into groups of lesser saddles and troughs. In the Pottsville anthracite basin, the anticlinal ridge called Mine Hill, trenched to its base at the passage of Mill Creek, and the W. branch of the Schuylkill, is a fine example of the normal wave. At both of these passes or gaps the regular arching of the rocks is so well exposed that every portion of the curve may be traced, and its changing inclination measured. The prevailing slope or dip in the S. flank of this wave is 40°, and in the N. flank 65°. The Gate Ridge near the S. side of the Pottsville basin is an instance of a more compressed normal flexure, its prevailing S. dips ranging from 45° to 55°, and its N. dips from 75° to 80°—the latter, however, becoming perpendicular, and even somewhat inverted, in the vicinity of Pottsville. All the flexures in the coal strata crossed by Silver Creek are of the normal type, except the most Southern, which has its N. flank inverted. On Casca William Creek, the coal-measures show five conspicuous waves, every one with a gentle S. dip, and a steeply-dipping N. side, in one or two cases inverted, or dipping S. In the Shamokin basin we have a good example of a normal flexure in Little Mine Ridge, in the S. slope of which the strata dip 20° S., in the N. 69° N. In the more uplifted region W. of the Susquehanna, this style of incurvation in the waves of the crust displays itself yet more conspicuously. The superior elevation of the waves there, conjoined with a denudation which has in many instances trenched out their summits, has developed their structure in the clearest manner, enabling the observer to contrast the slopes of their two flanks without any difficulty. In some cases he beholds the inner harder strata of the arch entire; in others he is enabled to reconstruct the broken arch, by prolonging the curves of its two abutments; and in nearly every instance he perceives a difference of from 15° to 30° in the inclination of the two sides; the N.W. dip, with a few exceptions, being the steepest. A traveller ascending the Juniata has an excellent opportunity for witnessing examples of this prevailing class of crust-undulation in Tuscarora Mountain, and in the pass of Jack's Mountain called Jack's Narrows, in both of which ridges the hard Levant sandstones span the anticlinal waves in almost unbroken crests. At the first-named ridge, the gentler or S.E. slope of the strata scarcely exceeds 20° at the river, and the N.W. is 35° or 40°; but when this wave is traced longitudinally from this point, which is near its termination S.W., to its central culminating portion, both dips increase, the S.E. becoming 40°, and the N.W. about 65°. The flexure which constitutes Jack's Mountain at the Juniata is a double wave, a bolder one sustaining a gentler one on its S.E. flank, but both of these possess the normal type: the principal wave, denuded at its crest, but entire as it recedes from the river, displays a N.W. dip of 75° or 80°, and a S.E. one of not more than 35°; the other, or flanking wave, a N.W. slope of 45°, and a S.E. one of 30°. Numerous instances of the smaller subordinate class of flexures present themselves along the Juniata, especially in the district between Tuscarora and Jack's mountains, but, with scarcely an exception, these conform to the same law of a steep and gentle slope.

The Pass of Wills' Creek Mountain W. of Cumberland, on the Potomac, is a highly picturesque example of a normal arch or wave, cut nearly to its base; and we meet with several beautiful instances of similar archings of the strata, on a grand scale, where the one side is more incurved than the other, in the central ridges of the mountain-chain in Virginia still farther S.

The Jura chain of Switzerland has been already referred to as containing many normal flexures. No one who has not travelled leisurely through the mountain gorges of that most attractive region, can conceive the grandeur and beauty of some of the wide-sweeping, lofty, semicircular precipices which there enchant the beholder in the Cluses or deep oval valleys, trenched by heavy waters out of vast wave-shaped mountains, of the class I am here describing. An American, familiar with the grand passes of the anticlinal ridges of the Appalachian chain, may get a conception of the far superior and wilder beauty of those of the Jura Mountains, if he will imagine the huge waves of his own strata to be three or four times as broad and lofty, and the strata themselves to consist, not of resisting sandstones, but of an alternation of deposits of soft shales and of thick-bedded limestones, the most picturesque of all rocks when carved into crags and cliffs.

Folded Flexures.—This *third* and remaining class consists of flexures in which there is an inversion, or doubling under, of the steeper side of each convex curve or wave (Fig. 703). When this structure is at a maximum, the folding back, downwards, of each convex or anticlinal arch amounts almost to a parallelism of the two branches or sides of the curve; and where there are several such foldings, alternately convex and concave, the strata may be said to be crimped or plicated into one dip, though the entire change of inclination through which the inverted portions have been bent, amounts to the supplement of the angle of the dip or the difference between the apparent dip and 180°.

It is a necessary feature of all such folded flexures, that the approximately parallel sides of the folds dip obliquely and not perpendicularly to the horizon. They are therefore but exaggerated instances of the class of normal flexures, or those where one branch of the curve is steeper than the opposite. As in the case of the normal flexures, the more incurved sides of these folded waves generally look the same way.

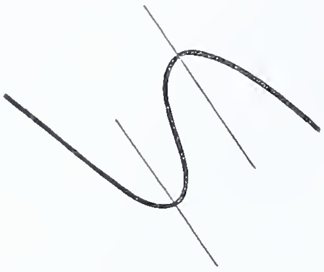


Fig. 703.—Folded Flexure.

An inspection of the general sections illustrating the Geological Map, and of many of the local ones, displaying the stratification in the S.E. portion of the State, will show that the flexures, with inversion of their steep sides, are chiefly confined to the Great Appalachian or Kittatinny Valley, and the Atlantic slope S. of it; though instances of this structure are to be met with N.W. of the Kittatinny Mountain, especially in the coal-measures of the Pottsville basin. The synclinal limestone valley of Montgomery and Chester counties is, in its central and E. portions, of this type; for while the strata of its N. side dip S. seldom steeper than 45°, those of its S. side near and E. of the Schuylkill are somewhat overthrown beyond the perpendicular. But it is in the district S. of this valley that we find the most numerous cases of oblique or folded flexures. Nearly every small insulated outcrop of crystalline limestone in the S. part of Delaware and Chester counties is an instance of a trough or little basin where the S. side has been folded over upon the N., until it has been squeezed down into a S. dip scarcely exceeding that upon which it leans.

The Kittatinny Valley is full of flexures of this extreme type, imparting a prevailing S.E. dip to the whole outcrop. Their number, and the excessive difficulty of detecting and continuously tracing them, frustrates every attempt at mapping them individually: nor was it deemed desirable, with the limited resources of the Geological Survey, to persevere far in a task promising little scientific or practical advantage.

Axis Planes.—It is convenient, for the purpose of expressing the kind of flexure, its degree, and its direction, to have regard to the geometric planes which bisect or equally divide the anticlinal and synclinal bends. These imaginary planes we have called the axis-planes of the undulations, being those which include all the horizontal lines or axes round which the individual concentric strata have bent in the act of undulating or folding. In the first-described class of flexures, or those of symmetrical curvature, each anticlinal and synclinal axis-plane is necessarily perpendicular to the horizon. In the second class, or the normal flexures, these axis-planes are necessarily not perpendicular, but steeply inclined to the horizon, and their deviation from the perpendicular is in proportion to the difference of inclination or of incurvation of the two slopes of the wave, modified, according to a certain law of variation, with the dip. In the third class, or that of flexures with *inversion*, the axis-planes are likewise not perpendicular; and it will be found that, in the great majority of instances, they dip with a less degree of steepness than the planes bisecting waves of the normal or other unsymmetrical type. Indeed, it may be stated generally, that, just in proportion as the flexure departs from the symmetrical-wave form, through greater and greater inequality of dip, up to parallelism of the inverted with the uninverted branch of the curve, the axis-plane departs from the perpendicular direction, to assume a less and less inclination to the horizon. In many districts of extreme plication of the strata—for instance, in the Atlantic slope of the Middle and Southern States of North America, also in the Bernese Oberland, in the Ardennes, and in North Wales—the axis-planes dip at an extremely low angle, consequent on the excessive amount of horizontal movement which the strata have undergone in the act of folding.

The positions and dips of the axis-planes are shown in the preceding woodcuts.

So nearly parallel are the inverted to the uninverted sides of the folds—the axis-planes all, of course, dipping one way—in many districts of close plication, that the detection of the anticlinal and synclinal bends is not a little difficult, especially where the sections, natural or artificial, are not perfectly clear of superficial debris. In such cases the whole plicated mass looks as if it contained but one dip, or consisted of only one thick sequence of deposits, instead of a much thinner formation many times reduplicated. To add to the liability of error, such bodies of folded strata are especially subject to that condition of jointage which is called *slaty cleavage*. In this structure, as I shall presently show, the divisional planes not only tend to obscure the original planes of sedimentation by their greater conspicuousness, but they often, by observing a very prevailing parallelism to the general dip of the folded beds, or, more strictly, to their axis planes, effectually disguise the anticlinal and synclinal curves. It is from these circumstances, and not from any erroneously-supposed power of truncation or denudation, to actually remove the anticlinal bends of the strata, that it is frequently so difficult to detect the true order of original superposition and the real thickness of closely-plicated formations. Of course, no erosion upon an anticlinal axis, however closely folded it may be, can obliterate the bends in those beds which have their curves below the level reached by the denuding agent.

Crust Waves, Straight and Curvilinear.—Regarding the great flexures of the crust as individual waves, which in truth they seem to be, we find them exhibiting, not only the above differences in the sloping of their two sides, but marked differences of form when viewed longitudinally. Thus, many are of extraordinary straightness; some of the larger simple anticlinals of the Appalachians being more than 100 miles in length, without any material or even perceptible horizontal crooking or deviation in their crest-lines. Others again are curved, some of these sweeping convexly towards the quarter of chief crust-dislocation and metamorphism, others curving convexly from it, but we never find these two classes associated in the same group, and in the Appalachians never even in the same segment of the undulated zone. In some districts of this and other chains, some of the principal curvilinear anticlinals and troughs are quite as extended in length as the great axes which are straight. They appear to be independent waves generated from curvilinear fractures of the crust, and not to be merely the bending terminations of adjacent rectilinear flexures. One of the most interesting features belonging to some of them is, their extent of curvature, and the graceful continuous smooth sweep which their curving axes present, often without jog or hitch, from one extremity to the other. This crescent-like form is developed in a high degree in those curving sections of the Appalachian chain, where the waves are convex North-westward, or from the quarter of maximum dislocation—the Atlantic slope. In the Juniata division of the chain in Pennsylvania, some of the curving anticlinals, 80 and 100 miles in length, change their trend between their two extremities as much as 40°; and in the Delaware division of the same chain, which bends with a concave sweep to the N.W., the deflection in more than one great synclinal trough and anticlinal axis is not less than 60°. This fact of the curvilinear form of anticlinals and synclinals of great length in this chain was long ago offered by us, as a phenomenon incompatible with the generalisation of the eminent French geologist, M. Elie de Beaumont, who conceives that the lines of elevation of the crust have been great circles of the sphere, and that those of a given geological epoch have invariably observed one constant direction. The whole of the Appalachian chain having been demonstrably corrugated into its present undulations at one epoch, that of the end of the coal period, the simple fact that its different groups of waves deviate as widely in direction from each other as 60°, while those of each group are reciprocally parallel—the whole chain indeed, if subdivided on this principle of direction, including not less than eleven conspicuous segments—is itself enough to show that no particular constancy of relation can be established between the dates of elevations and the mere directions of the lines or axes of the strata. But this other fact of so marked a change of direction in one and the same axis, as displayed by these crest-shaped waves, is, if possible, in still more striking contradiction with that hypothesis. Another fact connected with the groups of curving waves in the Appalachian chain is particularly deserving of mention in this place, from the bearing it appears to have upon the question of the direction of the pulsatory or wave-like motion of the crust, at the time of the permanent production of the flexures. This is, that the individual waves in all the segments of the chain which are convex North-westward exhibit, as already said, a continuous symmetrical crescent-like curvature; those, on the contrary, which are included in the other curvilinear districts, convex to the South-east, or towards the region of dislocation and metamorphism, present a much less regular incurvation along their anticlinals and synclinals, and a far greater amount of interference and of dislocation. These appear indeed to be the sections of the chain where the greatest amount of tangential wrenching, rupturing, and warping of the crust has taken place, and where the greatest amount of transverse hitching and fracturing has happened to all the strata. The causes of this difference will, I think, be seen, when I shall have developed our theory of the mechanical forces which undulated the Appalachian strata, and set in motion the stupendous billows of the crust, which resulted in the elevation of these mountains. An inspection of the best maps and sections of the more disturbed European zones, leads me to believe that a similar contrast prevails between the curvilinear waves which are convex to the districts of disruption, whence I suppose them to have proceeded, and those which are concave to the same quarters; but before this law in all its generality can be established, geologists must institute far more critical researches into the physical structure of those undulated and plicated districts than they have hitherto conducted.

Flexures or Waves of the Strata, regarded Longitudinally.—Having discussed the parallelism of adjacent undulations of the strata, their several specific forms, symmetrical, normal, and folded, the attitudes of their axis-planes; the straightness of some groups, the curvilinear shape of others; and shown their laws of gradation when severally compared, wave with wave, or group with group, it remains to trace the changing phases of a flexure as we view it lengthwise, or under the several aspects it assumes between its two extremities. Like all true waves or billows, every unbroken anticlinal flexure of the strata—and the description will apply equally to the synclinal, which are but their counterparts—has its maximum elevation in the middle of its length, its crest-line declining in a gentle curve both ways towards its extremities. Commensurate with this longitudinal subsidence, there is a flattening down of its two slopes, and a progressive approach in them to an equality of dip, until, near the terminations, there is seldom an appreciable difference in this respect: thus, the same wave, especially if it be one of the more majestic class, will present every gradation between its centre and two ends, from the normal, or even inverted type of structure, to the flat symmetrical. Crossed in its central portions, it may show the steeper flank thrown partially backward under the gentler; and receding towards either end, the inversion becomes a perpendicular dip, then a steep normal one, and as we still advance, this normal dip grows flatter and flatter, until towards the terminations it equals the opposite gentle one, and the two subside altogether; and this law of gradation holds true of all regular waves, whatever be their amount of flexure in the middle part. It is a consequence of this structure, or rather this structure arises from the fact, that in the middle parts of all regular anticlinals lower rocks than in the terminal are lifted to the same absolute level; they are indeed only very elongated oval bulgings of the strata, more squeezed on one slope than on the opposite, and their strata will be found to dip in all directions away from their primary axes of elevation. Hence, where great waves of the normal structure have been deeply eroded by excavating waters, they often exhibit in their central portion a long oval valley, formed by the cutting through of upper firmer rocks into softer lower ones. The floors of these valleys are merely horizontal sections of the uplifted waves, and generally reveal in their ground-plans the solid forms or styles of modelling of the uplifted billows.

Of the Distribution of Flexures into Groups.—Wherever, in the Appalachian chain, we become minutely familiar with the undulations of the strata, we find it impossible to resist the conclusion that the axes arrange themselves in natural groups. In those districts which are crowded with normal axes, such as the Susquehanna and Juniata divisions of the Appalachian chain, many such groups attract our notice; each assemblage is distinguished by some special character, and we are inclined to regard the comparison and analysis of their several features as of the very highest importance in those investigations of geological dynamics into which the whole subject of flexures evidently leads.

In the very interesting belt of parallel waves occupying Union and parts of Centre and Huntingdon counties between the Lewistown Valley and the valley of the Bald Eagle and West Branch, though there are three chief groups of anticlinal waves, these may be regarded as constituting one grand zone of singularly regular undulations. Viewed together, these waves are ten in number, the axis of each wave passing Eastward from a valley of Auroral limestone, or Matinal slate, through a beautifully-regular mountain-spur of the Levant sandstone, and expiring in the softer upper rocks on one or the other side of the Susquehanna. The ten mountain-ridges which express these ten undulations in the Levant strata are arranged in a beautifully symmetrical order, all of them, excepting the long spur of Jack's Mountain, throwing themselves successively farther Eastward the farther Northward they are. That they all constitute strictly a single group, lifted by the same crust-movement or series of movements, is palpable from the fact that their breadth or amplitude as waves, increases progressively as we cross them North-westward.

Another well-characterised belt of flexures fills the Lewistown Valley in Pennsylvania, applying this name to the whole of the long natural valley which extends from the Susquehanna to the Juniata, S.E. of Jack's Mountain. In a breadth of about 6 miles, there are here usually from five to six long, parallel, and gently-curving anticlinal axes, all of them of the normal form, resembling each other very nearly in the steepness of their dips, or average degrees of flexure. The lowest rocks which they lift to the surface are the Surgent shales, and the highest which their intermediate troughs have retained are the shales of the Cadent series.

A third very natural group of flexures is to be noticed in the E. part of the middle anthracite coal-field of Pennsylvania. The axes in question separate that region into an assemblage of small parallel coal-basins, of which the Beaver Meadow basin is one. Like the previous groups, these axes are characterised by their remarkable parallelism, their similarity in length, their gradually-increasing distances, and their gentle gradation in degree of flexure. They all of them bring to the surface the conglomerate which next underlies the coal; and the troughs which they form contain about the same moderate depth of Coal-measures, growing shallower, however, to the N.W. This collection of axes, unlike the two groups before described, constitutes a straight system.

If it were desirable, we might extend the enumeration of the groups of axes to every part of the Appalachian chain; but abundant evidence has been furnished to show that our anticlinal axes are not irregularly distributed, but maintain relations with each other, which require that they should be classified and studied collectively.

Their generic resemblances examined, they will be found to exhibit general laws and analogies that cannot fail to lead to some highly curious results concerning the forces which have thus undulated the earth's crust. That this curious and most instructive department of geological dynamics has escaped, until lately, the attention of the best investigators, we can only attribute to the fact, that in Europe no belt of axes, equal in extent to the Appalachian system, has come within the notice of geologists. Before a philosophical theory of flexures can be framed, large opportunities must be had for classifying their phenomena and tracing their laws of gradation.

GRADATIONS IN FLEXURES.

Gradation from the Folded to the Symmetrical Waves.—Several phenomena of gradation will be found to display themselves when we cross any broad belt of plicated and undulated strata. Starting from the side of maximum disturbance and contortion, invariably the quarter of maximum igneous action,—displayed either in Plutonic eruptions through the crust, in crust dislocations, or in metamorphism of the sedimentary rocks,—the flexures first met with are of the obliquely-plicated form. Advancing towards the middle of the zone, the folds become obviously less close; and proceeding still farther, they gradually open out, displaying more conspicuously their anticlinal and synclinal curves, until the inverted side of each wave becomes only perpendicular. This perpendicular altitude of the steep side soon becomes a dip towards the opposite quarter from that previously observed by both sides; and as we proceed, the steepness of the slope of the wave now rectified in position grows progressively less and less, until, on the far side of the zone, both slopes approximate to equality.

Gradations of Structure in Individual Flexures exemplified.—To render this subject of the gradations of phase in the same flexure more intelligible, I shall here cite a few instances from the Appalachian chain in Pennsylvania and Virginia. The relation between the degree of development or rise of the axis of an anticlinal undulation, and the steepness of its dips, is admirably exhibited in the great flexures which constitute the chain between the Susquehanna and the Potomac. Selecting as one of the chief of these, that grand N.W. one which encloses Nippenose, Nittany, and Sinking valleys, we can trace it through all its gradations, from the type of a flat symmetrical undulation at its extremities, to that of a greatly-lifted and compressed wave, with a perpendicular steepness on the N.W. side, at its middle part. Its total length is about 120 miles, its axis sweeping in a long and gentle curve from the table-land of Mahoopeny Mountain, at the sources of Little Muncy Creek, to the foot of the Alleghany Mountain west of the Blue Knob in Bedford County, traversing in its length the excavated oval limestone valleys, called Musquito, Nippenose, Nittany, Half-Moon, and Sinking valleys. At each end, and for a few miles, this flexure is flat, and of symmetrical or equal slopes; but approaching nearer the middle portion, it grows bolder, lifting the Levant sandstones into long pointed mountain-spurs, which ascending, divide into monoclinal crests. At these points, where it takes the names of Muncy and Brush mountains, the wave assumes distinctly the normal form, growing rapidly higher, and increasing in the steepness of its N.W. dip as it elevates lower and lower formations, until finally the great Auroral limestone rises to the day in Nittany and Sinking valleys. Between the ends of these and the centre of its range S.W. of Bellefont, the N.W. dip steadily steepens, until centrally it grows perpendicular, and even, in some places between Bellefont and Tyrone Gap, becomes a little inverted. In the vicinity of the Little Juniata, and apparently for some miles N.E., the flexure has given way at its axis, passing into a dislocation visible near the village of Birmingham.

We have another interesting example of a precisely similar gradation from the flat, symmetrical, steep normal structure, in the regularly crescent-shaped anticlinal wave, formed by the strata of Kishicoquillas Valley in Jack's Mountain. The axis of this flexure is traceable from the West Branch of the Susquehanna above Northumberland, to beyond Sideling Hill Creek, a length of 100 miles, and it goes through the same changes, except that it nowhere reaches an inversion of its N.W. flank. Tuscarora Mountain, Shade Mountain, Blue Mountain, Black Log Mountain, and Wills' Mountain in Bedford and Maryland, are all instances of a similar gradation of structure. Another fine example is that of Montour's Ridge, near the North Branch of the Susquehanna; though in this instance the wave only reaches a moderately gentle normal flexure at its midway section.

South of Pennsylvania the Appalachian chain contains many noble instances of normal and even folded flexures, displaying like degrees of alteration in their profiles from their extremities towards their centres. The Knobly Mountain of Virginia, the most Westerly large anticlinal wave S.E. of the coal-region, retains a normal profile in its strata through a length of more than 50 miles. Commencing near Cumberland on the Potomac, this wave-shaped mountain rises and widens, until, in Pendleton County, its N.W. dips become vertical, or a little inverted; and they retain this attitude for 40 miles farther S. to the anticlinal valley of Crabb Bottom. There passing the culminating part of its axis, the wave slowly sinks, and opens out, displaying its previous phases in a reversed order as it advances, until the divided crests close again by declension of the dip of the strata, and it becomes once more a gentle normal flexure, terminating finally at the S.W. in an inconspicuous low ridge or spur of equal opposite dips.

The Bull-Pasture Mountain of Pendleton and Bath counties, Virginia, displays the same gradual steepening of the flexure as its lower strata are successively lifted to the surface, and preserves in its central portion the normal profile without inversion, through a length of more than 50 miles. Jackson Mountain, in Virginia, is part of a great wave of the strata, which, commencing in Pendleton County, runs nearly straight to the deeply-scooped anticlinal valley of the Warm and Hot Springs, and terminates near Covington. Its length is about 70 miles. Manifesting at each end a gentle equal arching, the curvature or steepening of its strata in profile regularly increases, especially along its N.W. side. As far as the strong Levant sandstones span the wave, the mountain is single in its crest, but at the head of the Warm Spring Valley, and thence to the lower end of the Falling Spring Valley, this crest is parted into two ridges by deep excavation on the summit of the wave, the erosion having reached down to the Auroral limestone; and in this most lifted and laterally-compressed central portion, the N.W. side of the wave is perpendicular, and even inverted. At the end of the Falling Spring Valley the harder rocks of the mountain close over the slate and limestone of the valley, and the flexure begins to sink, contract, and flatten off in both its slopes, until at Jackson's River this prodigious wave of the rocks dies out in a low obtuse ridge of very depressed and nearly equal dips.

The very interesting relation here presented between the amount of incurvation or the steepness of the dips in flexures, and the amount of positive uprise of the strata, applies equally to the lesser or secondary anticlinal waves, and pervades every portion of the Appalachian chain. It constitutes an important law of structure connected intimately with the theory of a wave-motion of the crust, through which we seek to explain the curious phenomena of the undulated profile or wave form of the strata, so universal in all the disturbed districts of the globe.

Progressive Expansion of the Waves in one Direction.—Concurrently with this gradation, there is a progressive opening out of the spaces between the crests of the successive waves—such indeed as to amount in the Appalachians, and sundry other broad regions of crust-undulation, to an enlargement by many times of the amplitude of the more compressed class of flexures.

This remarkable and instructive fact is common to nearly all of the Primary class of undulations of the Appalachian chain, and is even common to many of the groups of secondary dimensions. It is manifested on a fine scale in the group of broad low waves which form the six finger-like mountain-basins in which the great bituminous coal-field terminates North-eastward, between the North Branch of the Susquehanna and the waters of the West Branch and the Alleghany River. It is one of several phenomena of gradation in the relations of the Appalachian flexures, which originally suggested to the author and his brother the theory of crust-undulations, or of a billowy upheaval of the strata, and is a fact which no other hypothesis of the origin of anticlinal and synclinal flexures can account for. Although distinctly noticeable in the N.W. side of the belt, the gradation prevails equally in the middle and S.E. tracts; but in the latter the numerous minor flexures, with the interference of groups of different dimensions, prevents our at first perceiving the law in all its simplicity and exactness. Towards the S.E. side of the chain, the flexures become so numerous, and are so often folded or inverted, as in most cases to render the comparison of their distances impracticable; yet even in this quarter, the general truth appears in the diminished space between the foldings as we cross the Great Valley southeastward. Viewing the whole breadth of the chain, the prevalence of the rule is obvious, no matter by what section we cross.

EXCEPTIONS TO THE PREVAILING LAW OF STEEPER N.W. THAN S.E. DIPS IN THE APPALACHIAN CHAIN.

There exist among the undulations of the strata in Pennsylvania a few—they are very few—exceptions to the almost universal law of a superior degree of abruptness of incurvation upon the N.W. slopes of the anticlinal waves. These abnormal instances of relative dip belong almost invariably to the secondary class of flexures, which I have never regarded as true waves pervading the earth's crust, but as comparatively superficial foldings occasioned by the joint agency of pulsation and lateral crumpling. There are a few examples of unusual steepness of the S.E. dips in the Primary class of flexures; but nearly every one of these exceptions applies to only a local portion of the wave, and will be found connected either with a fault in the strata, or with an oblique interference of the end of an anticlinal of another group. I think there does not exist within the whole wide undulated zone of the State, or of the Appalachian chain generally, a wave or group of waves of the first order, which is abnormal as respects the direction of the flatter and steeper slopes, except where we can directly refer it to the influence of some prodigious crust-dislocation.

As instances of exception to the general law, I may cite the second main axis of the Northern bituminous axis of the coal-fields, or that of the Towanda Valley. This is decidedly steeper in its S.E. dip than in its N.W. At the Susquehanna, the two inclinations, both gentle, are nearly equal; but the S.E. is greatly the steepest near the sources of Lycoming Creek, or in the direction towards which the flexure is expiring—a fact sufficient in itself to demonstrate that the irregularity is local, and proceeds from a twisting of the wave against another flexure. Chestnut Ridge, though normal in its profile on the Conemaugh, and, indeed, at both extremities of the long straight wave which it forms in one portion of its length, is locally irregular in the law of its dips, in consequence of an adjoining fracture in the strata at its E. base.

Of the lesser class of flexures of a reversed profile, we may instance many in the anthracite coal-fields, particularly in the Shamokin basin, and two interesting groups affecting the Scalent variegated and grey marls on the Juniata, of which drawings are appended for illustration.

One of these last-mentioned instances is to be seen in the cuts of the Pennsylvania Railroad, a short distance below Mifflintown, where there are three small flexures with their steep and gentle sides reversed, and one with symmetrical dips. The irregularity here is evidently connected with the dislocations indicated in the section. The other example referred to is to be met with in a series of cuts on the Pennsylvania Railroad, a short distance below Lewistown, on the Juniata. Here there are three flexures, all with their steepest slopes dipping to the S.E.

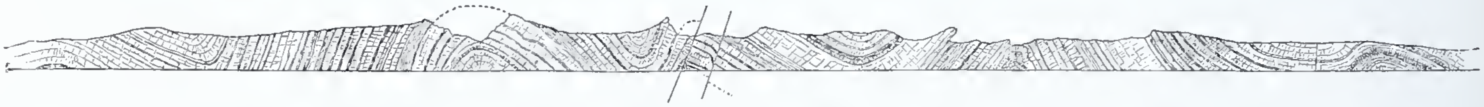


FIG. 704.—Undulations in Scalent Variegated Shales and Sandstones on Pennsylvania Railroad, Juniata River, below Mifflintown, Juniata County, looking S.W.—1 *inch* = 100 *feet.*

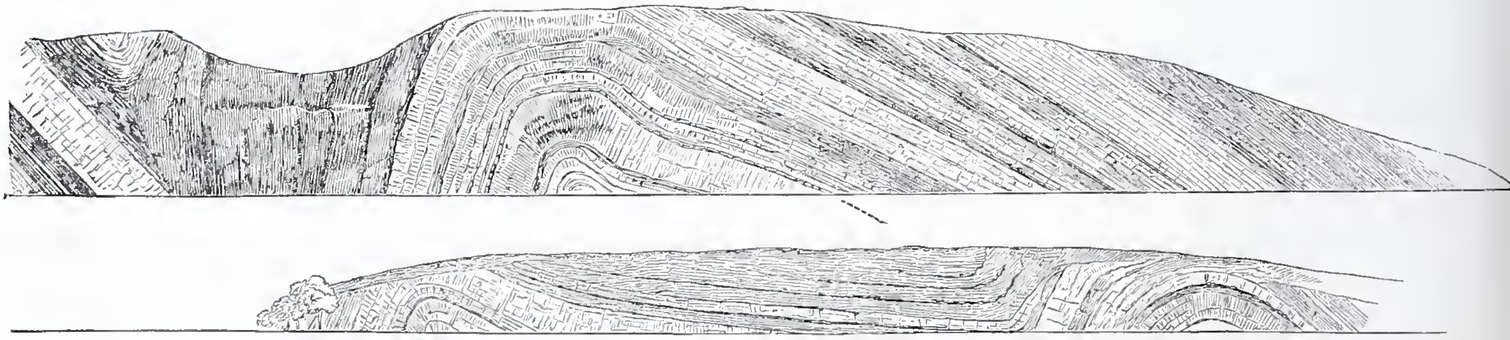


FIG. 705.—Undulations in Scalent Variegated Shales on Juniata River, below Lewistown, looking S.W.—1 *inch* = 50 *feet.*

A few other similar instances of irregular corrugation of the more pliable upper strata might be cited as occurring in the Lewistown synclinal valley, but the above examples will serve as types of the rest of these local rolls. It is worthy of note that the great anticlinal flexures bounding this long valley are all of them not only normal in their profiles or style of curve, but normal in the direction of their steepest slopes; even the four or five parallel undulations, of secondary magnitude, which lift the Pre-meridian limestone in long regular crests in the valley, between the Juniata and Jack's Mountain, observe the prevailing rule. I shall, in a subsequent chapter, when discussing the nature of the movements which undulated the Appalachian strata, advert more fully to the causes which seem to have produced these and other anomalies of dip.

Progressive Flattening-down of the Flexures.—A third feature of gradation shows itself in the progressive sinking or flattening down of the successive individual flexures, until these finally pass into horizontality. These three types of form in the waves, as respects their expansion, their increase of relative distance or amplitude, and their declining height, are conspicuously discernible wherever we cross the great Appalachian chain of the United States, by any section in a direction from S.E. to N.W. An inspection of the engraved sections illustrating our paper on the physical structure of the Appalachians,* or an examination of the more numerous similar diagrams explanatory of the geological surveys of New Jersey, Pennsylvania, and Virginia, will amply avouch for the correctness of this generalisation. It is further borne out in the published reports of the Government Survey of Canada, where the plicated structure of the Green Mountain range of Lower Canada, along all its S.E. border, and the universality of the S.E. dip of the folded strata—in other words, of the dip of the axis-planes,—is very distinctly set forth by Sir William Logan.

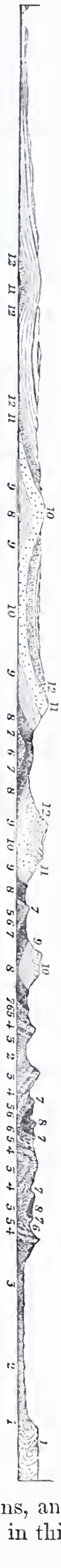


FIG. 706.—Generalised Section of the Appalachian Chain from N.W. to S.E., through the Juniata District of Pennsylvania.

Not only does the entire chain in its breadth exhibit a general gradation in the several features here described, but each of its great component groups of flexures presents the same progressive opening, recession, and flattening down of its waves in the same uniform N.W. direction.

Similar phenomena of gradation will, we feel assured, disclose themselves in any section made from the Taurus range N.W. through the Rhenish Provinces and Belgium, where, on the one side of the zone, the more ancient and much metamorphosed strata at the base of the Palæozoic system, according to the observations of Murchison and Sedgwick, present much reversal of the dip; one and the same dip—namely to the S.S.E.—being continued with very few exceptions across a belt of 50 miles, while on the opposite or N. side, the flexures of the Belgian coal-fields, so well shown in the beautiful sections of M. Dumont, are of the normal type, and much more open and dilated.

Nowhere perhaps in Europe are these gradations in the undulations of strata more beautifully exposed than on the flanks of the Alps. Deep in, towards its higher central igneous chains, the plication of its stratified rocks is excessive, and the inclination of the axis-planes remarkably low; but advancing outwards, the waves gradually lift their crests, throw forward their inverted sides, and assume that type of flexure which we have called the normal one; while again, at the outward base of the mountains, just before these undulations are concealed by the overlapping Tertiaries of the plains of Switzerland and of Northern Italy respectively, the curves become, in many instances, broad, depressed, and almost symmetrical in form.

From the descriptions here given of the structure of the Appalachian chain and other disturbed districts, it is obviously a general law that the axis-planes of the flexures are not only inclined all in one prevailing direction, though at different angles, but that they dip invariably towards the quarter or zone of maximum disturbance and rupture of the crust.

FRACTURES OR FAULTS IN TRACTS OF UNDULATED STRATA.

Two classes of dislocations abound in all zones of plicated and undulated strata, where the crust-waves exhibit much steepness, and especially where they have the inverted or folded form. By far the most numerous, though the shortest and least conspicuous class, are the breaks or faults which run approximately transverse to the strike of the anticlinal and synclinal axes. These may be extensively recognised in the Appalachians, where they are a primary cause of the deep ravines or breaches through the ridges, which furnish passage to nearly all the rivers, and even lesser streams, which drain this chain. Such ravines are especially frequent near the extremities of the large anticlinal waves, particularly where they have been cut through along their crests by denuding waters, and have given rise to valleys of elevation and erosion, enclosed by monoclinal outward-dipping sandstone ridges. It would seem as if the elliptical folding round of the strata towards the ends of the great denuded waves had caused the horizontal wrenching which resulted in these fractures. Mr William Hopkins of Cambridge, in an able paper on the subject of dislocations affecting dome-shaped elevations of the earth's crust, has indicated the true source, I conceive, of the double system of fractures to be met with in all elliptical anticlinal belts. An elongated anticlinal wave is, in truth, only a greatly-lengthened elliptical dome, in which the radial cracks caused by a maximum tension in the strata transmitted from the more central portion of the crust-wave, are distributed, some of them longitudinally, others transversely, as respects the anticlinal axis, the transverse ones multiplying themselves where the elliptical strain has been greatest, towards the two extremities of the waves.

Those parts of the Appalachian chain which most abound in the larger and more deeply-denuded class of anticlinal and synclinal waves in the strata, embrace many beautiful examples of the deep notches or gaps in the mountain-ridges, above alluded to as indicative of transverse breaks or dislocations in the rocks. They occur both in the sandstone barriers which surround the anthracite coal-basins, and in those which encompass the limestone valleys of the chain S.W. of the Susquehanna. It will suffice in this place to mention, as among the more interesting of the first-named series, the Mountain-gaps through which the upper branches of the Schuylkill and the Swatara rivers pass out of the Southern or Pottsville coal-basin, those by which the tributaries of the Mahanoy and the Shamokin leave the middle or Mahanoy and Shamokin coal-field, and those by which the N. branch of the Susquehanna enters and quits the Wyoming basin. Under the second head, it will be enough to call attention to the Kishicoquillas and Gosling Run gaps of Kishicoquillas Valley, and the sundry other deep mountain-notches which outlet the waters of the raised anticlinal limestone valleys and coves of this portion of the chain into the exterior valleys which hold the larger streams.

---

* Transactions of the Association of American Geologists.

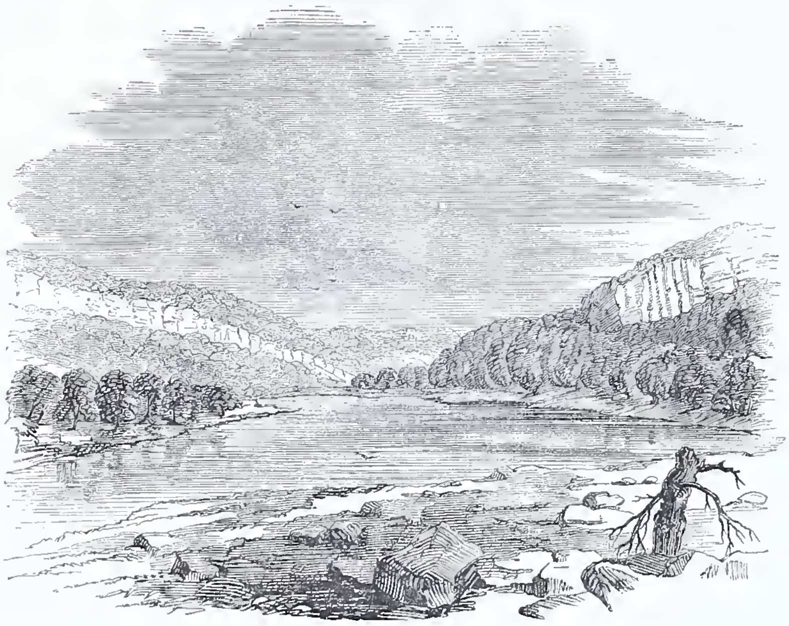


Fig. 707.—Delaware Water-Gap.

By far the larger number of these transverse ravines in the great ridges betray no perceptible horizontal displacement or heave of the rocks, though it is probable that a trivial amount of such actual dislocation does exist at nearly every one of them. In some of them, however, the break is very discernible, and in a few instances it becomes a conspicuous feature in the scenery. Thus the pass of the Delaware through the Kittatinny Mountain, called the Water-gap, shows a striking inequality in the inclination of the strata of the opposite sides of the gorge,—those of the New Jersey shore dipping at an angle of not less than 40°, while those of the Pennsylvania side decline as gently as 25°. As a consequence of this derangement between the opposite sides of the cross fracture, the summit of the mountain, or rather the same outcropping hard ribs of rock, appear thrown several hundred feet farther North on the New Jersey side than on the Pennsylvania.—(See View of Delaware Water-gap, fig. 707). There is a similar dislocation in the same mountain at the Susquehanna.

One of the most obvious of these transverse dislocations crosses Sharp Mountain, and the Coal-measures at Lorberry Creek, N.W. of Pine Grove, E. of the gap by which that stream passes through Sharp Mountain: the strata in this S. barrier of the coal-field range about S. 72° W., and dip in an *overtilted attitude*, at an inclination of rather less than 70° S.; while on the W. side of the gap, the course of the rocks is S. 57° W., their posture being nearly vertical,—the whole mountain, and the Coal-measures N. of it, being at the same time moved or heaved towards the S. as much as 30 yards.

It is probable that a fracture of the same kind passes through the gap of the W. branch of the Schuylkill, 2 miles W. of Pottsville; for the Coal-measures which E. from this neighbourhood are traceable with a moderate degree of regularity for several miles, appear no longer in their ordinary range when they are sought for on that stream.

Not unfrequently the cross dislocations are obliquely transverse, and not perpendicular to the strike of the strata; and in such cases, where the horizontal heave is considerable, we behold the two broken ends of the same hard belt of rock thrust past each other, as in the fracture of a man's thigh-bone. An example of this class of faults occurs on a grand and striking scale in Canoe Mountain, near the Juniata, at the point where the main road crosses the mountain. The ridge, composed of the Levant sandstones, here in full development, has been fractured in an oblique N.E. and S.W. direction; the Northern part has been shoved forward towards the N.W., and the S. forced past it N.E., so that they lap past each other. The ridge being double-crested, by virtue of the superior hardness of the lower and upper Levant sandstones compared with the middle, a directly transverse section crosses the mountain twice, crossing four summits instead of two.

The reader will find a cut displaying this dislocation in the chapter describing Canoe and Lock mountains.

There is a somewhat similar oblique lapping of a mountain-ridge of the Levant sandstones, from a similar cause, in the N.W. barrier of the Kishicoquillas Valley, opposite Belleville.

The anthracite coal-fields are full of such oblique fractures, causing the broken ends of the coal-beds to overlap each other.

The other far more conspicuous class of dislocations connected with these crust-undulations are the great longitudinal ones. These are of frequent occurrence in the more contorted portions of the Appalachian zone, especially in those where the chain is convex to the S.E., and in the straight sections of South-western Virginia and Eastern Tennessee. But I am persuaded, from the descriptions of geologists and from my own observations, that the fractures of this class are equally numerous in the Jura Mountains, in the Alps, in the district of the Ardennes, in Belgium, and in the mountain-chains of Scotland. A leading feature of these great fractures is their parallelism to the main anticlinal axes, or lines of folding of the chains to which they belong. They are, in fact, only flexures of the more compressed type, which have snapped and given way in the act of curving, or during the pulsation of the crust. They coincide, in the great majority of instances, neither with the anticlinal nor the synclinal axis-planes of the waves or folds, but with the steep or inverted sides of the flexures, and almost never occur on their gentler slopes. This curious and instructive fact may be well seen in the Appalachians of Pennsylvania and Virginia, by tracing longitudinally any one of their great faults from its origin on the steep flank of an anticlinal wave along the base of its broken crest to where the anticlinal form is again resumed. The following brief description, from our "Memoir on the Physical Structure of the Appalachians," taken from the *Transactions of the American Association*, will show the general phases through which these fractures pass :—

"From a rapidly steepening N.W. dip, the N.W. branch of the arch (or flank of the wave) passes through the vertical position to an inverted or S.E. dip, and at this stage of the folding the fault generally commences.

"It begins with the disappearance of one of the groups of softer strata lying immediately to the N.W. of the more massive beds, which form the irregular summit of the anticlinal belt or ridge. The dislocation increases as we follow it longitudinally, group after group of these overlying rocks disappearing from the surface, until, in many of the more prolonged faults, the lower limestone formation (Cambrian or Lower Silurian) is brought for a great distance, with a moderate S.E. dip, directly upon the Carboniferous formations. In these stupendous fractures, of which several instances occur in South-western Virginia, the thickness of the strata engulfed cannot be less, in some cases, than 7000 or 8000 feet."

One of these enormous faults in South-western Virginia has a length of more than 80 miles, and is almost perfectly straight. It follows the S.E. slope of Brushy Mountain, from the head of Catawba Creek to the vicinity of the court-house of Smyth County, engulfing all the strata of the S.E. half of a synclinal basin, of which Brushy Mountain remains as the other half. Where the dislocation attains its maximum intensity, or shows the greatest displacement of the strata, the lower formation—the Auroral Appalachian limestone, the equivalent of the Festiniog group of England—of one side of the fissure rests in an inverted attitude, with a gentle S.E. dip, directly on the South-east-dipping Vespertine grits and shales—represented in Great Britain by the lowest Carboniferous strata—forming the other wall of the fault.

General Parallelism of the Faults to the Axis-Planes.—It is a very general feature of the great longitudinal faults, whether these coincide with the anticlinal and synclinal axis-planes, or occur, as they more frequently do, on the steep sides of the flexures, to dip in the same direction with the axis-planes. In the Appalachian chain their inclination, therefore, is almost invariably towards the S.E. A consideration of the nature of the forces which have folded and ruptured the strata, shows that such a direction of their dip is an almost inevitable consequence of the undulatory movement. It is only in districts of low symmetrical crust-undulations, or those where the strata are absolutely flat, that the great fractures descend perpendicularly.

In corrugated zones, like those of the Appalachians, the Alps, and the Ardennes, the magnitude of these main longitudinal fractures, both as respects length and vertical displacement of the dislocated strata, is in proportion to the sharp bending or close folding of the waves to which they belong. Thus they invariably possess their grandest dimensions in the S.E. or most plicated belt of the Appalachians, or on that side of the zone where the crust-movements have been most energetic.

This obliquity or dip towards the quarter whence the movement has proceeded, is evidently the cause of that overlapping of the newer, less-lifted side of the wave in which the fault lies, upon the steeper, more perpendicular, or inverted flank ; for the forward or horizontal thrust which accompanied the propagated wave-movement resulting in the fracture, has, when this once occurred, found an inclined plane, up which the uninverted slope of the wave slid over the edges of the strata composing the inverted side. In many instances, as the Appalachian sections will prove, one flank of the wave has been shoved forward and upward, unconformably, upon the crushed and buried flank to an enormous distance. Subsequent erosion having cut down the higher strata of the up-driven, gently-sloping side of the wave, its lower beds are exposed to view, in immediate contact with the unremoved upper strata of the other side. Where the lower formations, cut into by the water on both sides of the fault, have been equally easy of excavation, especially where they are all of the same composition, as in the case of the great lower Appalachian limestones, the denuding waters have so effectually planed down the great inequalities of surface at first caused by the dislocation, as sometimes to have left in the landscape almost no external traces whatever of the gigantic rupture which lies beneath the soil. It is, then, only by a recognition of the ages of the respective strata, thus abruptly placed in contact, and usually, though not always, by some sudden difference of dip, that we are enabled to detect the presence and the magnitude of the dislocation.

Dislocation at an Anticlinal Axis-Plane—uninverted Side of Wave shoved over the Inverted (see Fig. 708).—It seems also necessary, on this occasion, to explain the effects of those great longitudinal obliquely-dipping faults, when they occur directly in the anticlinal and synclinal axis-planes, which are their occasional positions. The same forward upward-sliding, just described as having occurred where the fracture is between the anticlinal and synclinal curves, must have taken place where it has coincided with these; and as the movement must necessarily have been in the same direction—lifting, that is to say, the lower strata cut by the fault upon the edges of higher and higher beds, in the forward propulsion of the flat side of the broken wave—we have no difficulty in understanding how fractures in these positions, as well as in the other already spoken of, must have given rise to that very common phenomenon of the dipping of newer formations under older ones in plicated and dislocated countries like the Alps and the Appalachians. This puzzling feature of stratification, long an enigma to geologists, can, I conceive, be explained upon no other analysis than that which is here given—namely, the oblique folding of undulated strata, the obliquity of the planes of the faults, either coincident with, or parallel to, obliquely-dipping axis-planes; and the forward upward thrust of the uninverted upon the inverted broken strata, through a tremendous tangential force incident to a wave-motion.

Dislocation at a Synclinal Axis-Plane.—Where the dislocation has taken place, as it very frequently has, in the plane of a synclinal fold, it has generally been accompanied by a similar forward and upward thrust of the strata above the fault, but these strata belong in such instances to the inverted side of the adjacent anticlinal wave. This kind of fracture and displacement presents, therefore, an inverted set of strata, resting over an uninverted or right set, a relation the converse of that which characterises a dislocation at an anticlinal axis; but the relation of the strata brought thus unconformably into contact as respects their stratigraphical position is the same as in the cases of fracture through the axis-planes of anticlinals; for the movement being an upthrow of the overlying mass in the plane of the fault, its effect, conjoined with denudation, has been to display lower rocks leaning invertedly upon upper.

The accompanying diagrams are designed to illustrate the several conditions of contact of strata displayed by faults coincident severally with anticlinal and synclinal axis-planes, and by faults parallel with these, but situated in the overturned and crushed sides of steep folded flexures.

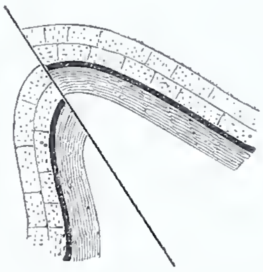


Fig. 708. — Upward displacement of uninverted side of fractured anticlinal.

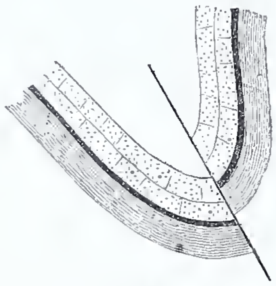


Fig. 709.—Upward displacement of inverted side of fractured synclinal.

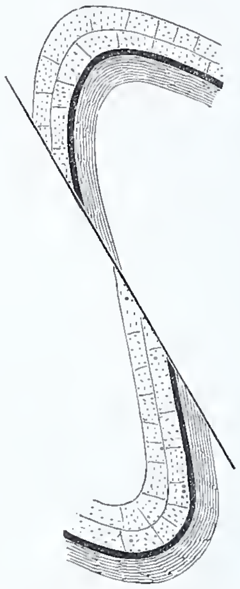


Fig. 710. — Upward displacement of whole anticlinal flexure; fault in the inverted side.

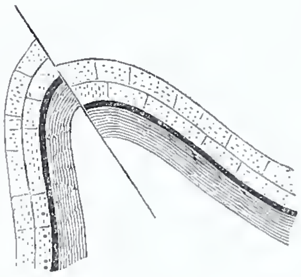


Fig. 711. — Downward displacement of uninverted side of fractured anticlinal.

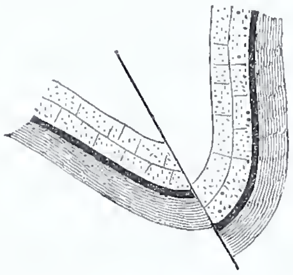


Fig. 712. — Downward displacement of inverted side of fractured synclinal.

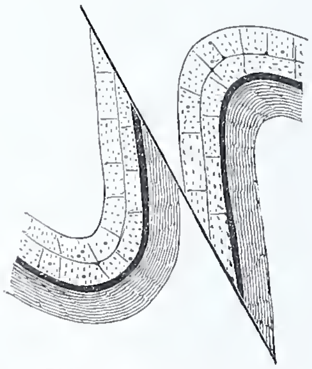


Fig. 713.—Downward displacement of whole anticlinal flexure; fault in the inverted side.

Instances of great Longitudinal Dislocations.—Numerous instances of longitudinal faults, nearly all of them dipping obliquely, and for the most part South-eastward, are to be met with in the Pottsville coal-field and other disturbed plicated belts in Pennsylvania. The principal features of the lesser ones—which are chiefly interesting where they affect the Coal-measures—have been already described in that portion of this work which is devoted to the Anthracite region. It will suffice here to exemplify our general statement of their nature, by pointing to one or two of the larger dislocations of this type to be met with in other parts of the State.

An interesting longitudinal dislocation ranges along the W. margin of M^{c}Connellstown Cove. From its N. end Southwards, it buries successively Cadent, Meridian, Pre-meridian, Scalent, Levant, and Matinal rocks under the Auroral limestones of the Cove, and Southward it allows them to rise out again in a reversed order. Near the middle of its length, inverted South-east-dipping Auroral limestone leans at a steep angle on the more gently South-east-dipping higher Cadent and even Vergent rocks. This great fissure evidently dips steeply towards the E.S.E., and has its place about half-way between the anticlinal axis of M^{c}Connellstown Cove and the synclinal of the mountain-trough of Scrub Ridge; it therefore belongs to the N.W. flank of a great wave, and not to either axis. There is an interesting smaller fault in Path Valley, W. of Fanettsburg, the features of which have been shown in the chapter giving the geology of that district. It is to Virginia and Eastern Tennessee, however, that we must look for the grandest and most instructive examples of the class of great longitudinal faults.

Those not unfrequent instances of a **Y**-shaped branching of a dislocated bed of coal, known to miners in the Pottsville and other disturbed coal-fields, are for the most part cases of fracture at the synclinal turn of the coal-bed, with an upthrow or shoving upward and forward of the steeper near side of the trough, unconformably upon the far side (see Fig. 709). We have a good instance of this in the narrow broken basin of the so-called Peach Mountain Coal-seam, on Silver Creek, and some of the streams which cross it farther E. The **Y** is formed by the steeply North-dipping S. side of the trough overriding the gentler-dipping N. side, and it leans as the letter does, if we assume ourselves looking Westward. Here the plane of the fault has been almost coincident with the top slate of the South-dipping bed.

An opposite case sometimes occurs of a **Y**-shaped branching of a faulted coal-bed, where the stem of the **Y** ascends, and the fork is downward, like the letter **Y** inverted; thus, **⅄**. This is simply an example of a dislocation at or near a sharp anticlinal flexure, the broken-off leg of the wave having been *moved after the fracture upward and forward unconformably over the inclined edge of the other portion* (see Fig. 708). Like the previously-mentioned **Y**-shaped fault, this **⅄**-shaped dislocation has the plane of the sliding nearly coincident with the coal forming the longer branch; but it is the longer leg, and not the shorter, which has in this case shoved itself over the other, and the fault is under, and not over it.

EXEMPLIFICATION OF THE LAWS OF FLEXURE BY THE PHENOMENA OF SOME OF THE UNDULATED ZONES OF EUROPE.

Analogous Phenomena of Axes in Great Britain and Ireland.—A perception of the important and novel bearings of the curious laws of structure here described upon many points in geological dynamics has led us (Professor W. B. Rogers and the Author) to examine with deep interest the valuable and accurate labours of Fitton, Martin, De la Beche, Dumont, Murchison, Sedgwick, Weaver, Hopkins, and other eminent European geologists, in the expectation of finding in the phenomena they describe evidences of analogous laws.

While studying with this view such memoirs, sections, and maps as were within our reach, we have enjoyed no small gratification in discovering what we consider numerous striking proofs of the prevalence of similar structural features in some of the most interesting geological regions in Great Britain and on the Continent.

Among these we would first mention the peculiarly interesting districts of Wales, to which the admirable researches of Sedgwick and Murchison have imparted so high a geological importance.

In the beautiful and elaborate works of the latter geologist, the publication of which forms one of the great eras in geological science, we think we discern very distinct proofs that the Cambrian and Silurian axes of Wales possess similar structural features with those of our Appalachian chain. While the older strata of the Berwyn Mountains, as described by Sir Roderick Murchison in his *Silurian System*, would seem, by their altered character and frequently inverted dips, to mark a close proximity to one of the great lines of disturbance of the district,—that lying towards the N.W., from which a combined uplifting and tangential force has been propagated; the contour of the undulations lying more towards the S.E., when unaffected by faults or local disrupting action, exhibits a general conformity to our law of a steepening flexure on the side towards which the movement has proceeded. As illustrations of this law, we would beg to refer the reader to a few of the sections appended to Murchison's work on the *Silurian System* :—

1st, Plate XXXI. fig. 5.—Section across the Ludlow and Brecon Anticlinal, exposing the Valley of Elevation of Wigmore Lake.

2d, Plate XXXIV. fig. 3.—This exhibits to the N.W. the lower Silurian *on end* for some distance from its contact with the Cambrian, after which it passes by a bold sigmoid flexure, in which the S.E. dips are *very steep*, beneath the upper Silurian.

3d, Plate XXXIV. fig. 9.—Displays an *inverted* and *folded flexure*, succeeded by steep S.E. dips in the flagstones of the Cambrian, following which are two *normal arches* in the lower Silurian.

To these sections may be added the vignette, page 359, presenting an axis in the Cambrian rocks of Caermarthenshire.

In the E. portion of this district, bordering the Malvern Hills, according to the same law, the flexures would appear to be related to the great line of elevating action, extending in a N. and S. direction through that region. The *steeper* sides of the arches are now towards the W., and the lower rocks are often overturned, so as to dip towards the E., thus exhibiting a direction of flexure nearly opposite to that of the strata near the Berwyn chain. As examples of these phenomena, we would refer to Plate XXXVI. fig. 8, presenting a transverse section of the Malvern and Sedbury hills, and Figs. 9, 9 b, and 10 of the same Plate, exhibiting the structure of the Woolhope axis.

The same general structural features will, we confidently believe, be found to prevail in the perplexing stratification of those parts of Devonshire and Cornwall, which elicited some years ago so much earnest theoretical discussion among British geologists. An inspection of the sections accompanying Sir H. De la Beche's elaborate report—those, for example, from Combemartin to Bolthill, and from Linton to Bideford—and a careful examination of the descriptions of this region given by him in that work, and by Sedgwick and Murchison in their very able memoir "On the Physical Structure and Older Deposits of Devonshire," induces us to venture the prediction, that throughout the region to which they refer, the phenomena of folded axes will be found of very extensive occurrence, and that this folding and inversion, together with the general law of steepening flexure in a particular direction, will explain the frequent repetitions of certain groups of strata, and assist in removing much of the obscurity which still hangs round the intricate geology of some parts of that district.

Similar indications are, we think, presented in the structure of the S. and S.E. parts of Ireland, as described by Weaver, Griffith, Hamilton, Austin, and others. Among these may be instanced *the great predominance of S. dips*, those to the N. being only occasional and of short continuance; a result, in our view, naturally arising from a succession of folded and steeply normal flexures due to a pulsatory movement propagated from the S. The evidences of such foldings and inversions are, we think, quite observable in the account given by Mr Weaver of the parallel bands and patches in echelon of the older limestones, while the steepened dip and extensive folding and inversion among the higher rocks, resulting from the same forces, are strongly implied in the section given by the same author through the Dromagh coal-field.* Similar phenomena would seem to be referred to also by Mr Austin, when, in speaking of the neighbourhood of Waterford, he ascribes the numerous contortions of schistose rocks, considered by him as being of the age of the Silurian, *to excessive lateral pressure.*† From the observations of Dr Fitton on the structure of the Wealden and associated formations, as detailed in his admirable memoir on the strata below the Chalk, and likewise from the more recent investigations in the same region by Mr Hopkins, of which a summary is to be seen in the *Proceedings of the Geological Society of London* for 1841, it would appear that in the districts of the Wealden and Bas Boulonnais, the numerous axes observe a *curved* form, and are nevertheless *parallel* to one another. Mr Hopkins, after describing several of these flexures, states that "all these lines observe a remarkable parallelism with each other, and with the curved central axis of the district." It would further appear, from the observations of these distinguished geologists, unless we have given an erroneous interpretation to their sections and descriptions, that a great number, if not all of these axes, present a much steeper dip on one side than on the other, and that this stronger inclination generally occurs on the same side—viz., *the Northern one.* Speaking of the line from Farnham to Seven Oaks, Mr Hopkins uses these words, "It is a line of flexure,‡ with a great dip to the N., but without the corresponding dip to the S. necessary to form an anticlinal arrangement, except in one or two localities. Towards the W. it runs immediately at the foot of the Hogsback, with a dip which, near its W. extremity, amounts to 70° or 80°. Tracing it towards the E.," he adds that "at some points the line assumes a distinct anticlinal character."

Dr Fitton, in describing the interior of Kent (pp. 134 and 135), gives several drawings of sections of this or an adjoining axis, in all of which the predominance of the dip on the N. side is distinctly marked. Alluding to one of these sections, he says,—"Both sides of the saddle are visible within a few paces; the beds on the N. rising at an angle of about 60°," while on the S. they decline at an angle of 45°. As illustrating the same law, we would more particularly refer to the following coloured sections appended to Dr Fitton's Memoir:—

1. The section across the Weald, from the South Downs, Western Sussex, to the Surrey hills. In this the dip on the N. side of the great axis is represented as slightly greater than on the S. side.

2. The two combined sections along the S.E. and S.W. coasts of the Isle of Wight. The axis traversing this island, and continued to Purbeck, is represented on the map accompanying the Memoir of Dr F. as parallel with that of the Weald. The sections referred to cross this axis, and exhibit a much greater steepness of dip on the N. than on the S. side.

3. The three sections across the Vale of Wardour transverse to the axis of that region. In all of these the preponderance of dip on the N. side is very great.

This series of curved or undulating axes, which are in the main parallel to each other, would thus appear to manifest laws of structure strictly analogous to those of our Appalachian region; and they serve still further to confirm us in our belief of the prevalence of similar features among the flexures in all regions of extensive disturbance, as well as to increase our reliance on the justness of the theoretical views by which we have attempted to explain them.

In conclusion, we would express our belief, founded on the phenomena referred to in this chapter, and on numerous similar geological facts, of recent as well as ancient date, which cannot be mentioned in this place, that all great *paroxysmal actions*, from the earliest epochs to the present time, have been accompanied by a *wave-like motion of the earth's crust.*

Belgium and the Rhenish Provinces.—Embracing in one view the undulated districts of Southern Belgium, the Rhenish Provinces, the Westphalian coal-field, the Ardennes, the Hundsruck, Taunus, and Hartz ranges, as described and mapped by M. Dumont and other geologists, we can discern most distinctly all the phenomena of flexure and of dislocation of the strata, here indicated as characteristic of the structure of the Appalachians. We there perceive a wide zone of crust-undulations having its strata most invaded by igneous rocks, and most ruptured and metamorphosed along its S.E. side, and displaying its most ancient sedimentary formations in a state of close plication, with innumerable inversions of the dip, imparting to wide tracts one uniform parallel inclination towards the S.E. Crossing the zone N.W., we enter newer and newer strata, until we come to the undulated coal-field of Westphalia or Belgium, our traverse taking us from the non-fossiliferous formations, at the very base of the Palæozoic system. In whatever meridian we make our section, we find the N.W. sides of the waves, with few exceptions, steeper than the S.E. ones, not only where they are inverted, but where they have a normal dip. We find, moreover, as we advance, that the waves grow more and more open, and that the distances between them increase; that they subside in height, and that the two slopes approximate nearer to equality. These gradations are admirably disclosed in any traverse across the strike N.W., from the water-shed of the Ardennes to the Belgian coal-fields of the Meuse. I can detect, in the features of Dumont's exquisite map of Belgium and the neighbouring countries, the very same relations of the longitudinal faults to the flexures that have engendered them which prevail in the fractures of the Appalachians above described. They evidently, for the most part, occur on the N.W. sides of the anticlinal axes, and cause older strata to ride upon newer ones plunging under them, with approximately parallel dip. Even the phenomena of cleavage, presently to be described, will be seen to exhibit the very same laws in the metamorphic S. half of this wide zone of plication, which they present along the S.E. side of the Appalachian chain, and the Atlantic slope bordering it. This region of the Rhenish Provinces and Belgium further agrees with the Appalachians in being a zone of undulations and plications, where the folding movement has been all in one direction.

---

* See "Memoir on the Geological Relations of the South of Ireland," by Thomas Weaver, Esq., *Trans. Geol. Soc. Lond.*, 2d Series, Vol. V.

† See *Proceedings of the Geol. Soc. Lond.*, No. 74.

‡ By the term flexure, as explained by the phrase *one-sided saddles*, used in the same connection, we infer the author to mean what we denominate *oblique flexures*, while he restricts the term anticlinal to those bendings which give approximately equal dips on the opposite sides.

The Jura Chain of Switzerland.—The Jura chain of Switzerland, as I pointed out in 1848, in communications to the Geological Society of London, and in 1849 to the American Scientific Association, is another very interesting belt of crust-waves, displaying in its structure a close resemblance to the Appalachians.

It embraces, like the American mountains, many groups of waves differing in the directions of their axes in different districts of the chain, the individual groups being composed of waves which are remarkably parallel. Few of these undulations exhibit actual inversion of their steeper sides, the dip in some instances passing the perpendicular, and generally not exceeding on an average 70°, the gentler or opposite slopes only having a mean slant of about 40°. In four traverses which I made across this chain, I observed one almost invariable law as to the direction of the steep and gentle sides of the undulations, or, in other words, of the axis-planes. Contrary to first anticipation, and to the belief of many Swiss geologists, I found the steeper curvature of the waves directed toward the Alps, and not from them, implying that the crust-movement which lifted these grand and picturesque arches proceeded from the N.W., and not from the chain of the Alps. This also is a belt whose undulations are chiefly in one direction.

The Alps.—The great chain of the Alps is much more complex in its structure than either of the undulated zones yet described. It contains but few waves of the open or normal type, but innumerable close foldings or plications. Throughout a great portion of its length, this lofty and rugged zone of mountains consists of two approximately parallel chief crests. The great feature in the geological structure of the whole zone is the presence of belts of closely-plicated Mesozoic and Tertiary strata on both flanks of each of these great constituent ranges. But the most striking, and, at first view, perfectly enigmatical feature, is the inward plunge of the newer strata beneath the older, in the sides and at the base of both chains. When, however, the plicated strata are structurally arranged and traced, we find that this phenomenon assumes the character of a symmetrical folding of the rocks in two opposite directions from each high central axis. The individual foldings, with scarce an exception, lean outwards from the central tracts of the mountains, or from the quarters of igneous disturbance, rupture, and maximum metamorphism of the crust: in other words, the axis-planes of the plicated strata of the flanks of the Alps dip inwards towards the centre of the chain; those nearest to it at a low angle, and those more remote at angles steeper and steeper as the waves recede, expanding to the outer base of the range. High on the flanks of the Alps, or, what is the same thing, deep in towards the roots of the mountain, where only the synclinal bends of the flexed strata have been protected from denudation by inward folding, these closely-compressed troughs lie pinched in between the older strata in oblique inward inclination. The transverse sections expose these bendings, which are called V's by some of the Swiss geologists. Here then we behold an exact counterpart in the stratification or structure of a single flank of the Alps, of that folding with inversion which characterises the Appalachian chain, or that of the Ardennes, a single side of the Alps being the equivalent of the whole of either of those zones; it consists, that is to say, of a belt *undulated in one direction.* Crossing the Alps, or rather one of its component great chains, we find another *similar* belt of the same strata, plicated in the same way, with their axis-planes dipping also under the crest or orographic axis of the mountain, but of course to the opposite quarter of the compass as compared with the plicated zone of the other flank. This is, I conceive, a correct picture of that feature which, hitherto imperfectly analysed, has been called by some of the geologists of Switzerland, expressively enough:

The Fan-like Structure of the Alps.—Viewed as a single chain, this mountain system consists, then, of two belts undulating in opposite directions; but, as already stated, it is for the most part of its length a double chain; and I think each range, especially where these are widest apart, has a plicated belt of strata upon each of its slopes, so that, for some distance at least, the fan-like structure is twice repeated; in other words, there are four belts of closely-folded waves, each having its axis-planes dipping towards the base of its own high mountain system.

A conspicuous and pervading cleavage-structure coincident in the direction of its dip, as I shall presently show, with the oblique axis-planes of the folded rocks, contributes greatly, I conceive, to the illusive phenomenon of an inward dip of all the strata, or to that general feature which has been called fan-shaped.*

This inward dip is rendered still more obvious by the circumstance that the foliation or crystalline lamination of the more altered strata itself obeys very generally a similar law of parallelism to the axis-planes of the flexures.

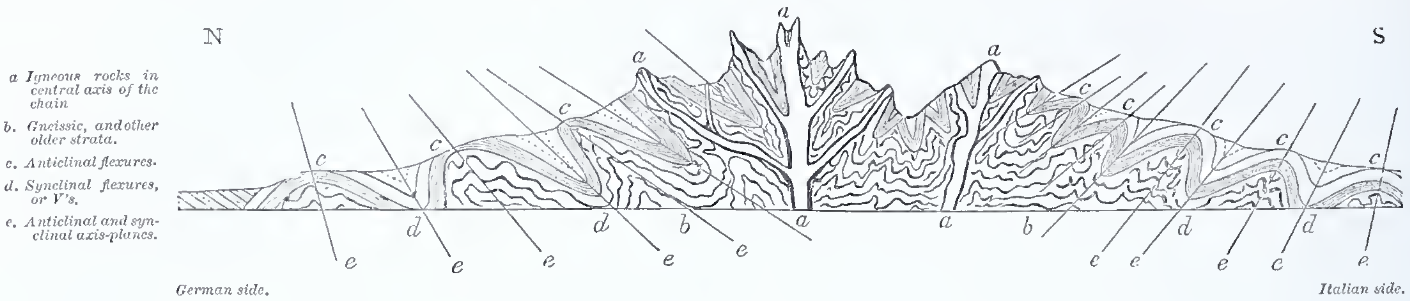

N
S
a Igneous rocks in central axis of the chain
b. Gneissic, and other older strata.
c. Anticlinal flexures.
d. Synclinal flexures, or V's.
e. Anticlinal and synclinal axis-planes.
a
b
c
d
e
German side.
Italian side.

Fig. 714.—Generalised Section of the Alps, displaying the Dipping of the Folds of the Strata on both Sides in towards the Igneous Axis.

Where this crystalline grain of the rocks does not coincide with the stratification, it exhibits a great tendency to a coincidence of dip with any system of cleavage-planes belonging to the same or other parts of the mass. In either case it will dip inwards towards the igneous axis of the chain, if the strata possessing it are themselves closely folded in conformity with the prevailing law. But the phenomena of cleavage and foliation will be noticed afterwards. We now proceed to discuss the

GENERAL PHENOMENA OF SLATY CLEAVAGE IN THE APPALACHIANS, AND OTHER ZONES OF PLICATED STRATA.

Cleavage approximately parallel with the Strike, but independent of the Dip of the Strata.—It is now a good many years since Professor Sedgwick and other geologists announced the important general fact that the structure called *cleavage* pervades the altered strata affected by it, in directions independent of their bedding or laminæ of deposition. That eminent geologist further announced that these planes are approximately parallel to each other over large spaces of country, however contorted the dip of the rocks. He likewise enunciated a second general law of much importance, " That when the cleavage is well developed in a thick mass of slate rock, the strike of the cleavage is nearly coincident with the strike of the beds." Subsequently Professor Phillips gave to this rule of the cleavage a still more comprehensive and exact expression, when he stated to the British Association in 1843, that the cleavage-planes of the slate rocks of North Wales are always parallel to the main direction of the great anticlinal axes. Other geologists have abundantly confirmed these generalisations. Since 1837, these phenomena of the close parallelism of the cleavage-planes of a given district with each other, and with the main axis of elevation of the district, have been constantly observed and recorded by my brother, Professor W. B. Rogers, and myself, in our Geological Surveys of Virginia, Pennsylvania, and New Jersey.†

In 1849 I submitted to the American Association for the Advancement of Science, at the annual meeting held at Cambridge, Massachusetts, in a communication on the analogy of the ribbon structure of glaciers to the slaty cleavage of rocks, a statement of what I had for some years previous regarded as the true law of the direction of the cleavage-planes of a district of undulated and plicated strata.

In its simplest expression the rule is, that *the cleavage dip is parallel to the average dip of the anticlinal and synclinal axis-planes*, or those bisecting the flexures. The generality of this rule was shown on the occasion mentioned, by sections exhibiting the flexures and cleavage in the Appalachians, in the Alps, and in the Rhenish Provinces; and I have since become convinced of its universality from the inspection of the phenomena of other districts, and from a study of the descriptions and sections of geologists. Want of space prohibits me from here citing the abundant evidence for this law to be found in the best recently-printed memoirs upon slaty cleavage; but I hope to be able ere long to give my own observations in support of the highest British geological authorities, who, unaware of the relationship itself, have furnished the most satisfactory data for the recognition of it. I cannot, however, refrain, in this place, from sustaining the generalisation I am here venturing to put forth, by instancing the support it receives from the excellent descriptions recently given by Professors Harkness and Blyth of the Cleavage of the Devonians of the South-west of Ireland. In their paper in the *Edinburgh New Philosophical Journal* for October 1855, they not only establish an agreement between the strike of the cleavage-planes with that of the several rolls (or anticlinals) which affect the island of Valentia, but they show that, while the cleavage dip is S., the anticlinal "curves have been pushed over in a more or less N. direction," inverting the carboniferous limestones and coal-measures. Their general statement is, that the cleavage-structure of rocks does not result from the simple rolling of the strata, but from this cause combined with a considerable amount of pressure; and this latter force acting from the S., has pressed over the strata in a series of oblique curves to the N., and given to the inclined cleavage its greater or lesser degree of S. dip. They support the doctrine of Mr Sharpe respecting the cleavage of rocks,—"That there has been a compression in the mass in a direction everywhere perpendicular to the planes of cleavage, and an expansion of this mass along the planes of cleavage in the direction of a line at right angles to the line of incidence of the planes of bedding and cleavage;" or, in other words, to the direction of the dip of the cleavage. From this view of the mechanical nature and direction of the force engendering cleavage, I beg leave respectfully but explicitly to dissent.

---

* From the analysis above given of the structure of the sides of the Alps, it will be seen that I entirely concur with Professor James Forbes, and with all the more eminent of the Swiss geologists, in recognising the fan-like dip of the newer strata, Tertiary and Mesozoic, conformably in appearance at least under the older strata, metamorphic and gneissic, of the higher more central tracts, and that I dissent entirely from the theoretical section offered by Mr Daniel Sharpe.

† See Annual Reports on those Surveys, 1837-40, and other Essays.

Fan-like Arrangement of the Cleavage at the Anticlinal and Synclinal Axis-Planes.—A second general fact or law of direction of the cleavage-planes in folded strata must be here enunciated. At first view it is in seeming contradiction with the universality of the primary rule above stated, of the invariable approximate parallelism of the cleavage-planes to the axis-planes of the flexures; but closely examined, it will be seen, I think, to be in beautiful accordance with that law, and with my hypothesis of the origin of the cleavage-structure. The rule is this, that where the cleavage is fully developed, and the anticlinal and synclinal flexures are also conspicuous and very sharp, the cleavage-planes immediately adjoining those bendings are not parallel to the axis-planes, but partially *radiate from them in a fan-like arrangement* upwards in the anticlinals, and downwards in the synclinals.

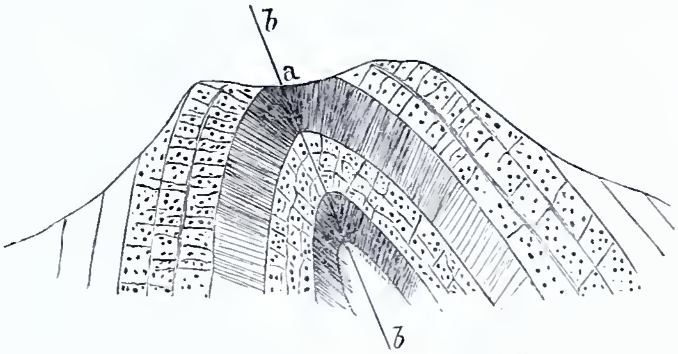


FIG. 715.—Fan-like arrangement of Cleavage at an Anticlinal Axis.

This aberration from the normal direction is furthermore different in degree upon the two sides of the geometric axis-plane, being usually greatest upon the inverted or steep side of the wave.

Another aberration of the cleavage-planes from their normal direction of parallelism to the axis-planes, is their tendency to conform partially to the dip of the strata, when the two are nearly coincident. This operates to flatten the inclination of the cleavage upon the gentler slope of each wave, and steepen it upon the more inclined one; and as in every belt of uniform flexures closely plicated with inversions, the uninverted or normal dips greatly exceed the inverted ones, it produces in such cases a prevailing lower inclination in the planes of cleavage than in the planes bisecting the flexures.

Relation of Cleavage to the Mechanical Constitution of the Strata.—There is yet another law respecting cleavage; it is the dependence of this structure upon the mechanical texture, and possibly upon the chemical composition, of the fissured rocks.

Geologists have for several years recognised the fact, that in formations composed of alternations of the coarser mechanical rocks, such as silicious grits and conglomerates, with fine-grained argillaceous beds, as slates, shales, or marls, the coarse beds are unaffected by cleavage, while the fine-grained ones are often pervaded by it. Indeed, one may observe in a given locality almost a strict proportion between the degree of intimate fissuring of the rocks by cleavage-planes, and the degree of comminution of their particles.

Connected probably with this interruption in the distribution of the cleavage-condition through such heterogeneous groups of strata, I have observed another general fact of modification of the cleavage-planes, which should not be passed unnoticed here. They tend, in the fine-grained argillaceous beds, to curve a little from the normal direction into an approach to parallelism with the surfaces of bedding of the adjoining coarser mechanical deposits, presenting, in a transverse section, a kind of gentle sigmoid or double flexure. This is well shown in the cleavage-traversed rocks at the base of the anthracite coal-formation of Pennsylvania, especially in the transition or passage beds which connect the Umbral red shales of that region with the base of the coal-sustaining conglomerate, and also where these shales alternate with the upper coarser members of the Vespertine sandstone. The small section here appended, showing the cleavage, in one of these groups of alternation of red shale and

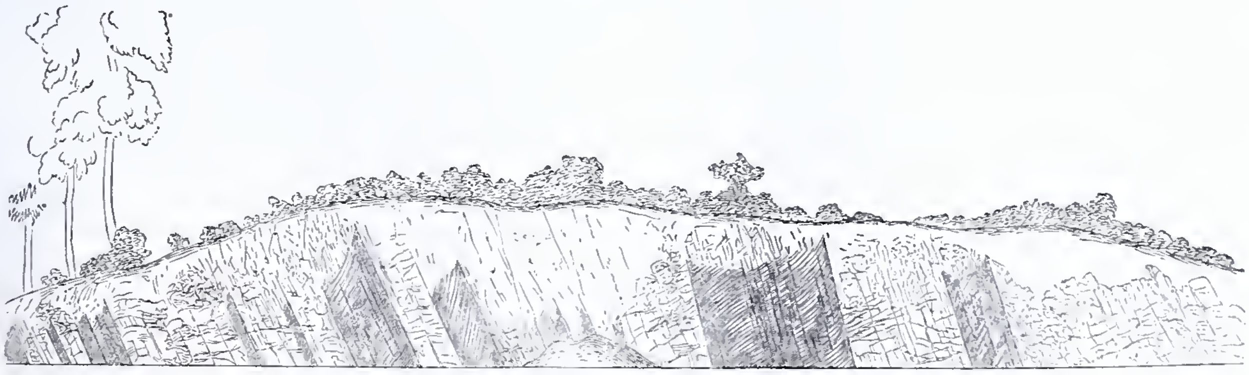


FIG. 716.—Beds of Red Shale with Cleavage alternating with beds of Sandstone without Cleavage; Cleavage curving towards parallelism with the bedding at its boundaries. Section near Ashland, Pennsylvania.

sandstone, from a railway-cut near Ashland, in the middle anthracite coal-field, exemplifies well the phenomenon referred to.

The tendency here shown in the cleavage-planes to conform to the planes of bedding, where abrupt changes of composition interrupt the continuity of the fissures, is but another variety of the phenomenon already adverted to, of a deflexion of the cleavage in bands of plicated strata towards a parallelism with the gently-dipping slopes of the anticlinal waves. This remarkable fact of an intimate dependence of the cleavage upon the composition and mechanical texture of the structure is, I conceive, of itself sufficient to refute the hypothesis somewhat in favour at present, of the purely mechanical origin and nature of the cleavage-producing force; for we cannot conceive how a mechanical force, either of compression or of tension, transmitted, as necessarily it must be, very equally through parallel layers of coarse and fine materials, should have exerted no fissuring action the moment it reached the surfaces of the coarser beds, and yet have been able to cleave into thin parallel slaty laminæ the whole body of the fine-grained argillaceous strata. One would more naturally suppose that the less firmly aggregated softer mud-rocks or shales would have been even less easily fissured by sharp cleavage-joints than the more massive and better cemented grits. It is of importance to notice here, that subsequent disruption of the strata may change the normal position or dip of the cleavage after its formation, and give rise to some of the apparent deviations from the general law of direction above enunciated.

The Cleavage Susceptibility alternately greater and less in Parallel Planes.—Cleavage is a susceptibility in rocks of a certain composition, and in a particular stage of metamorphism, to split in definite straight parallel planes. The cohesive force is obviously at a minimum of intensity in the direction perpendicular to these planes. In the other two rectilinear axes of the cube, one side of which is coincident with the cleavage-plane, the force of cohesion next in degree of intensity is the horizontal one, or that in the direction of the strike of the cleavage, while the most intense cohesion of all is that in the direction of the cleavage-dip. It is in this latter direction that the molecular forces of attraction engendering incipient crystallisation seem to have been most powerfully awakened, while the polarities have been feeblest in the lines perpendicular to the cleavage-planes; but apart from these three directions and grades of corpuscular force, we have indications, in any homogeneous mass of cleavage-traversed slate, or other rock, of the presence of two grades of the minimum cohesion, constituting the cleavability, disposed side by side in alternate parallel order; in other words, where the cleavage is fully developed, the rock will be found to contain certain nearly equidistant closely-contiguous planes of maximum cleavability, or, what is the same thing, of minimum lateral cohesion—the material of each thin plate of the slate cohering more strongly together than these adjacent plates cohere to each other. The existence of such planes is indicated by the manner in which any mass of very cleavable slate, long exposed to atmospheric agencies, invariably breaks up, as we may see in any naked outcrop. If the cohesion of the mass in a direction perpendicular to the cleavage-planes were equally strong in all parallel planes that we can imagine pervading it, it is impossible to understand how any uniformly-acting disintegrating forces,—either expansion and contraction by heat, soakage and drying, or freezing and thawing,—could subdivide it by planes or fissures so regularly distributed as we find them. These could only have arisen, I conceive, from the presence of parallel planes of weaker and stronger cohesion. In this interesting structure we discern a striking analogy to that alternation of thin plates of solid blue crystal ice, and white porous ice of less cohesion, which is so distinct a feature in the fully-developed ice of glaciers, and which has been expressively named by Professor James D. Forbes the Ribbon Structure.*

FOLIATION.

The relations of the foliation or crystalline lamination of metamorphic strata to the cleavage-planes and the planes of stratification, come next to be considered. Two facts may be stated of foliation, which possess, perhaps, the constancy of general laws. One of them is, that this structure, as it is seen in gneiss and mica-schist, observes, when the strata are not traversed by cleavage, an approximate parallelism to the original bedding. Apparent exceptions to this rule occur in several localities near Philadelphia, and elsewhere in the United States, and have often been noticed in Europe by Mr D. Sharpe and other good observers; but all of them can be reconciled to the general fact, and reduced, it is conceived, to one comprehensive law—namely, that the planes of foliation, or the laminæ, formed by the crystalline constituents of the foliated rocks, are *parallel to the planes or waves of heat* which have been transmitted through the strata. Wherever large tracts of the gneissic rocks retain a nearly horizontal undisturbed position, the foliation is almost invariably coincident with the stratification; and in this case, the wave of heat producing the crystalline structure can only have flowed upwards through the crust, invading stratum after stratum, in parallel horizontal planes. Again, when injections of granite occur in uplifted gneissic strata, the crystalline lamination is generally seen to be parallel to the plane of outflowing temperature. The other general rule is, that *the foliation is parallel or approximately so to the cleavage*, wherever these two structures occur in the same mass of rocks. This fact, recorded by Darwin, of the gneissic rocks and clay-slates of South America, has been noticed likewise by Mr D. Sharpe, Mr David Forbes, Mr Sorby, and other geologists in Great Britain, and by the Author in many localities in Southern Pennsylvania, and in other districts of the Atlantic slope. An interesting instance of such parallelism of the foliation to the cleavage, tending to show convincingly that both phenomena are the consequences of one species of force, or are only different degrees of development of the same molecular or crystallising agency, is presented in the great synclinal trough of the lower Appalachian limestone, North of Philadelphia. On the N. side of this trough, the Primal and Auroral rocks dip S. over a wide outcrop at a very regular angle of about 45°. On the S. side they have been lifted into, and even a little beyond, the perpendicular position, so that the synclinal axis-plane of the belt dips at an angle of 65° or 70° to the S. Neither formation shows cleavage-structure on the N. side of the valley, the limestone being there of an earthy texture, and in thick massive beds, but on the S. or upturned side this limestone is altered into a mottled blue-and-white crystalline marble, and is pervaded with cleavage-planes, dipping at angles of 70° and 80° S. Many parts of the rock are like a foliated calcareous gneiss, thin laminæ of mica and talc dividing the slate-like plates of the marble. It is especially worthy of notice that the foliation of the mica and talc, composing some of the thin partings between the original beds of the limestone, is itself very generally parallel to the cleavage in the adjoining calcareous rock. Indeed, wherever the cleavage is excessive, the mass becomes, by introduction of fully-developed talc and mica between its laminæ, a true foliated stratum. An especial interest annexes to cases of this kind, from their showing that, in the contrasted conditions of the absence and presence of metamorphism in the two opposite outcrops of the same synclinal fold, both effects, cleavage and foliation, have originated at the same time, and from one and the same cause, and are, in truth, but different stages of the same crystalline condition, superinduced in the mass by high temperature at the period of its elevation. The above general fact of the prevailing parallelism of the foliation to the cleavage, is but a corollary of the more general relationship already expressed of the parallelism of the resulting planes of crystallisation to the waves of heat which have produced the metamorphism.

---

* In a communication submitted to the American Association for the Advancement of Science, in 1849, I attempted to show this analogy of the ribbon structure of glaciers to the slaty cleavage of rocks, in the following remarks:—"The ice of glaciers consists of thin alternate parallel bands or plates of blue crystal ice and white porous ice, each not more than $\frac{1}{3}$ or $\frac{1}{2}$ of an inch in thickness. These pervade the whole mass of every glacier, and are clearly exposed on the sides of the transverse fissures. Near the sides of the glacier they are almost absolutely parallel with its mountain-walls, but they sweep away towards its medial line, and form, like all the other planes which divide the glacier, a series of innumerable loop-like curves. This looped or festooned form is obviously caused in part by the downward tendency of the movement or flow of the semi-plastic ice, and in part by the influence of the terminal moraine to induce that parallelism to itself which the rocky sides of the glacier produce in the ice near them. The most general fact noticeable in relation to these structural planes is the approximate parallelism to the rocky walls and terminal moraine confining the icy-mass; or, in other words, to the surfaces of higher temperature which enclose the glaciers. However the direction of the ribbon-lines may alter by irregularities in the onward flow of the glacier, their position near the region of the nevé is strictly parallel with the surface of the warmer mountain-sides."

EXAMINATION OF THE PREVAILING THEORIES OF ELEVATION.

Perhaps the most current notion respecting the force which has displaced and elevated the originally horizontal strata of the globe, is that which represents the granitic and volcanic rocks as forcibly injected in a melted state into fissures, and violently thrust in solid wedge-shaped masses upwards through the incumbent crust. That this is the prevailing idea is apparent from the manner in which nearly all geological sections, even the most modern ones, designed to represent the relations of the Plutonic to the sedimentary rocks, are to this day constructed. Where igneous rocks constitute the whole or a large portion of the central axis of a mountain chain, or even that of a simple anticlinal ridge, they are usually represented in cross sections, in the form of a broad wedge, and the stratified rocks are drawn as leaning upon the sloping flanks of the wedge or prism. This is not, I think, the true relation in nature of the igneous to the sedimentary masses, as I propose to show from the following considerations.

Hypothesis of Wedge-like Intrusion of Melted Matter.—The notion of an upward wedging, or intrusion of molten mineral matter into or through the superincumbent strata in the manner of a wedge, implies a function in the soft material which belongs to the mechanical action of a solid, and is incompatible with the dynamic properties of fluids. Until a fissure from below first penetrates or traverses the invaded overlying strata, it is not possible to conceive that the liquid matter could introduce itself in the mode of a wedge. Some force must first crack the crust, and then the molten matter, flowing into the fissure, may act as a narrow wedge or key, to keep the walls of the chink distended; but such plates of solidified refrigerated volcanic matter, known as veins and dykes, must necessarily be narrow, and have the shape rather of walls with parallel surfaces than great wedges broad at the base.* They will also abound chiefly in the districts of subsidence, or in the concave waves, not in those of elevation, or in the convex, where the wedge-like form tapering upwards is usually represented. Where a rupturing of the strata has taken place in a tract of elevation, or at an anticlinal, the fissure or fissures will be found to gape upwards, and the melted volcanic matter which has flowed to the surface will be seen widening outwards, and tapering as it descends—the very opposite of the form usually assigned to such outbursts in the igneous axes of uplifted chains. So common is this upward enlargement of the Plutonic masses in certain regions, that it constitutes, I conceive, one element of the fan-shape or inward dip of the boundary walls of the rocks, so frequently encountered in the Alps and other much-disturbed mountain-systems. A true conception of the formation of a mineral vein or dyke will represent it as the *consequence*, not the cause, of the fissure which it fills, the real process being, not a protrusion of the fluid matter through the crust, breaking it in its passage as a solid wedge might, but an actual injection or pumping of it into the newly-opened vacuous cavity, from the pressure or tension below.

---

* It is in consequence of this natural expansion of surface-cracks outwards in anticlinals, that the miner so frequently finds his mineral lodes contracting or dying out as he descends. Several striking instances of this thinning of veins downwards could be cited from the mines of the United States situated in anticlinal flexures.

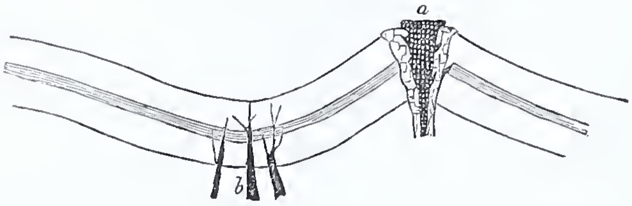


Fig. 717.—Dykes expanding upwards in Anticlinals and downwards in Synclinals.

Intrusion of the Igneous Rocks in Solid Wedges.—The other notion, frequently connected with the above idea, of a forcible propulsion of igneous matter through the crust, is that of the violent thrusting upward of volcanic or granitic matter already solidified, in broad wedge-like masses through the strata. This conception I hold to be at variance both with sound mechanical laws and with the physical facts. For the solid igneous mass to have acted in the manner of a wedge, it is absolutely necessary that it should have moved freely upward through the opening in the strata, which it is supposed to have wedged apart and to have uplifted, and even corrugated, by lateral compression. But it is impossible to imagine such a slipping of the assumed granitic wedge past the edges of the strata confining it, since we can imagine no force acting downward upon these latter, to prevent their moving upward along with the wedge of granite, nor any localisation of the force below, to prevent it operating on both alike. We have furthermore no evidence of that discontinuity between the igneous rock and the ruptured strata, which the notion of a sliding wedge obviously pre-supposes, but, on the contrary, every proof, from general theory and from observed facts, that the two descriptions of rock are intimately bound together in closest crystalline contact, keyed together by veins, branching from the mass of the one into the fissures of the other, and even fused together by an actual incorporation of substance. Any upward movement, therefore, of Plutonic masses, bearing sedimentary rocks upon their flanks, cannot have been in the manner of a mechanical wedge; and those results—corrugation, for example—of the adjacent strata, habitually attributed by many geologists to an imagined wedge-like lateral thrust, must be accounted for upon some other sounder mechanical theory.

A modified form of this conception of an igneous wedge lifting and displacing the strata, assumes no sliding or wedge-like protrusion of the solid granitic matter past the edges of the rupture in the bedded rocks, but, recognising the inseparable cohesion of the two, regards the stratified masses flanking the anticlinal mountain as merely borne upward by the uprising of the central igneous nucleus. I deem this notion to be a much truer picture of the procedure of nature; for it so far accords with what we notice in anticlinal districts having igneous crests or centres, that it represents the stratified rocks leaning against the walls of the great granitic central dykes, at steeper and steeper angles, the higher we ascend towards the summits. It is inexact, however, in picturing the granitic nucleus of the anticlinal mountain as a wedge or broad prism tapering upward, for reasons already shown. Undoubtedly such a mountain if we can imagine it denuded or truncated to lower and and lower levels, would disclose a progressively increasing quantity of intrusive igneous rock, but this would be in the multiplication of the lateral granitic injections, and it is only in this erroneous sense that the igneous nucleus can be regarded as a prism. Its cross section is branching rather than wedge-like.

The Upward Movement of an Igneous Dyke would tend to Stretch and not to Corrugate the Flexible Strata.—The view here admitted of the elevation of the igneous nucleus of a mountain, along with the strata which mantle it, while it is perfectly compatible with the hypothesis, to be hereafter advanced, of the origin of anticlinals generally, is wholly inconsistent with the somewhat current notion of the mode of origin of undulations and plications in the stratified rocks, by pressure from the tangential horizontal thrust of such uprising igneous axes: so far from its producing a lateral corrugating pressure upon the strata adjoining, and resting against it, a central granitic or other igneous dyke lifted vertically by one or many successive movements, paroxysmal or gradual, would rather *stretch* or distend the strata as it carried them upward than compress them.

Theory of Upward Tension against Lines or Points of the Crust.—Another common theory of crust-movement and elevation of anticlinal belts supposes, vaguely, an upward tension or stretching of the crust of the earth along one or several lines, or at one or several focal points, without attempting to account for the linear or focal force, or to assign a cause for the restricted limits within which it is assumed to act. This conception, though confessedly indistinct, is frequently appealed to in explanation of the lifting of mountains, the corrugation of strata, and even the formation of regular groups of parallel anticlinal waves. I propose to consider its weak points.

Any theory henceforth admissible into physical geology must explain the now clearly-established general fact of the regular wave-structure of the earth's disturbed zones. But this wave-structure cannot be interpreted on the mere supposition of simply an upward pressure exerted either along one or many lines. The peculiar configuration of the crust-waves, shown in this paper to be characteristic of them in all undulated regions, requires an hypothesis which will furnish both an undulating and a horizontal tangential motion; moreover, the ordinary doctrine, if it assumes the pressure from beneath to be exerted along a single line at a time, fails altogether to show us how this pressure could have shifted to new and parallel lines, or how it could take up new positions, and exhibit that relation of relative distances constantly widening, which is seen in all undulated belts. No simple upward pressure along a line in the crust could form a defined or limited anticlinal flexure. Whether the pressure were exerted by a liquid or a solid subterranean mass, it would produce rather a wide general moderate elevation, than a narrow, sharp, anticlinal wave.

If, again, this vague theory be modified to admit the action of a series of simultaneous linear pressures, coincident with the observed anticlinal flexures of an undulated district, it is not possible to understand why, being contiguous, they should not all conspire to lift the outer mass or crust into one general bulge or broad distended dome, rather than into a series of alternately synclinal and anticlinal waves. In addition to these difficulties, this notion of self-awakened linear pressures contains no clear hypothesis of the *origin* of the linear forces.

Hypothesis of Corrugation from Sinking of Tracts of the Earth's Surface.—Another theory of the cause of flexures in the crust conceives them to have been produced from a sinking of the ground by removal of matter by volcanoes, or by the contraction of argillaceous rocks by heat and pressure. Sir C. Lyell, who appears to advocate this view, supposes that pliable beds may, in consequence of unequal degrees of subsidence, become folded to any amount, and have all the appearance of having been compressed by a lateral thrust; and the creeps in coal-mines are adduced as affording an excellent illustration of this fact.* With every respect for this eminent geologist's ingenious views, I must confess that this conception seems to me quite as much beset with difficulties as the somewhat kindred theory of elevation and simple upward protrusion. Apart from the objections that it supplies no cause for the peculiar shape of the crust-waves, nor any explanation of their parallelism and their remarkable laws of gradation, it appears to me quite inadequate to account for lateral corrugation at all, or for more than a very insignificant amount of it. A downward pressure or tension over a single area, produced by release of support arising from vacuities beneath the surface, ought not to engender, on any known mechanical principle, a series of flexures, either within or around the area, but should result in a mere subsidence or flattening of the portion from whence the support has been withdrawn. If the centring of a very flat dome, too weak to sustain itself, be removed, the dome either suddenly collapses with a fracture, or it indents itself, and sinks where it is weakest and most yielding, till it meets the supporting floor. Before the wide nearly level dome of a segment of the earth's crust can corrugate either itself or the adjoining strata, some alternate upward and downward force must undulate them, or they must contain alternate weak and strong belts, and even then these must be somewhat undulated; none of which conditions the hypothesis of subsidence is prepared to supply.

Hypothesis of a simple Horizontal Compression.—A somewhat favourite and familiar mode of accounting for the undulation and plication of strata, is that which assumes them to have been corrugated by a purely horizontal or tangential pressure, without elevation and without pulsation; and this imagined mode of folding has been ingeniously illustrated by Sir James Hall, Sir H. De la Beche, and other geologists, by their placing flexible layers of clay, or cloth, or other substances, horizontally under a weight in a trough, and forcing one or both ends towards the centre, so as to contract the length of the strata, and thereby produce a series of miniature plications. It has been alleged that this folding of the clay or cloth is an exact imitation of the flexures of strata seen in nature; but I must deny the assumed analogy. The plications thus produced are merely irregular contortions; they exhibit no definite form of curvature, no constancy in the direction of their gentler and steeper slopes, and no law of regular gradation. Their anticlinal and synclinal axis-planes, if they can be said to have any, lean some one way and some another; and the flexures, when the crowding is great, have a tendency to the horse-shoe form, and not to that of waves.

This hypothesis of corrugation, while it is erroneous in thus failing to present a true representation of the waves of the crust, is also defective in its mechanical principles, for it assigns no cause for the origination of the wave-structure. A purely lateral or horizontal force should, as already intimated, simply bulge out to a feeble extent the whole compressed arch, but ought not of itself to wave it; some independent agency, producing alternate upward and downward flexure, is indispensable to give even the most powerful tangential pressure the ability to plicate the flexible mass. This hypothesis is furthermore imperfect in not suggesting any cause in nature for the assumed horizontal pressure. It has been already shown, when discussing the hypothesis of simple elevation, and of simple subsidence of areas of the earth's crust, that neither of those movements, unaccompanied by an actual pulsation of the strata, would be competent to corrugate the crust at all; the mere elevation of an igneous axis having the tendency to stretch rather than compress the adjoining strata; and the simple sinking of an area, by retreat of support beneath, having only the effect to warp the surface irregularly, but in nowise to undulate it.

VIEWS OF GEOLOGISTS CONCERNING CLEAVAGE AND FOLIATION.

Professor Sedgwick, as early as 1822, discovered and subsequently publicly taught the true nature of slaty cleavage, distinguishing it from joints, and showing it to be a tendency to separation in perfectly parallel planes, which are irrespective of the bedding. He ascertained that the slaty cleavage is usually confined to the finer-grained rocks—alternating coarser beds possessing it very imperfectly—and laid it down as a rule, that the *strike* of the cleavage is nearly coincident with the strike of the beds. He referred it to crystalline or polar forces acting simultaneously and somewhat uniformly in given directions. Subsequently, in 1835,† after many additional observations on the modifications of slaty cleavage, he showed that the rule admitted of many limitations, which the geologist is compelled to notice in working out the structure of complicated districts. In a recent publication, his *Synopsis of the Classification of the British Palæozoic Rocks,* he proves conclusively that the cleavage structure is "the compound effect of all the crystalline forces acting on the mass, and that it cannot be due to a mechanical action." In this work he also mentions the important fact of the existence frequently of a second cleavage-plane, generally inclined at a great angle to the primary.

---

* See LYELL'S *Elementary Geology*, 5th edit., p. 50.

† Geol. Trans., 2d Series, iii. 461.

Sir J. Herschel has suggested that the rocks possessing cleavage may have been so heated as to allow a commencement of crystallisation, or heated to a point at which the particles may have begun to move among themselves, or on their own axes; surmising that some general law has determined the positions on which the particles have rested on cooling, and that this position has had some relation to the direction in which the heat escapes.*

Professor Phillips† has shown that, in some slaty rocks, fossil shells and trilobites have been much distorted by cleavage; and he imputes this to a creeping movement of the particles of the rocks along the cleavage-planes. This displacement, uniform over the same tract of country, he states to be as much as a quarter or even half an inch. Hard shells are not thus affected, but only the thin ones. Professor Phillips, in 1843, stated that the cleavage-planes of the slate rocks of North Wales are cleavages parallel to the main direction of the great anticlinal axes.

Mr Daniel Sharpe conceives that the present distorted form of the shells in certain slates has been produced by a compression in a direction perpendicular to the planes of cleavage, and an expansion in the direction of the cleavage dip.‡

He conceives that the planes of cleavage range vertically along certain lines or belts, and dip towards those lines on each side of them; those nearest the central vertical belts at high angles, the angles gradually diminishing as the distance from the vertically-dipping cleavage increases. This is his explanation of the fan-like arrangement of dip noticed in some countries. "This regularly-descending series of planes being found on each side of parallel lines of vertical cleavage, the two series either meet in the centre in a sort of anticlinal axis, or coalesce into an arch. The planes between two lines of vertical cleavage appear to form a complete whole, and the area bounded by the vertical cleavage may be considered as belonging to one system of cleavage, and may be called an area of elevation of the cleavage." He thinks the cleavage-planes are really parts of great curves, which, if completed, would represent a series of semi-cylinders turned over a common axis.

Mr Sharpe thinks "that there is reason to believe that all slaty rocks have undergone a compression of their mass in a direction perpendicular to the planes of cleavage," connecting with this view his supposition that the cleavage arrears are great anticlinal waves. He supposes that the compression of the slaty mass, and its expansion in the direction of the cleavage dip, have been due to the stretching of the strata in the direction of the curve representing the cleavage dips.

Mr Charles Darwin,§ reviewing his observations on cleavage in South America, says,—"The cleavage laminæ range over wide areas with remarkable uniformity, being parallel in strike to the main axes of elevation, and generally to the outlines of the coast." He recognises the fact that the cleavage-planes frequently dip at a high angle inwards, and he cites an instance of cleavage dip, in the mount at Monte Video, where "hornblendic slate has an E. and W. vertical cleavage, with the laminæ on the N. and S. sides near the summit dipping inwards, as if the upper part had expanded or bulged outwards." Mr Darwin first proposed the term foliation for the laminæ in gneiss and other crystalline rocks, or the alternating layers or plates of different mineralogical composition. He pointed out the parallelism of the planes of foliation of the mica schists and gneiss with the planes of cleavage of the clay-slate in Tierra del Fuego and Chili, as seen by him in 1835. He conceives that foliation may be the extreme result of the process of which cleavage is the first effect, or that the crystalline form may have been most energetic in the direction of cleavage. He further suggests, "that the planes of cleavage and foliation are intimately connected with the planes of different tension to which the area was long subjected, after the main fissures or axes of upheavement had been formed, but before the final cessation of all molecular movement," "and that this difference in the tension might affect the crystalline and concretionary processes."

Mr Sorby, adopting the mechanical theory of cleavage, maintains that it varies directly as the mechanical changes, and inversely as the chemical (molecular) changes, which the strata have undergone. He thinks he has shown that the cleavage of certain limestones, microscopically examined by him, varies directly as the amount of mechanical compression to which they have been subjected, and that this compression was such as would necessarily change the structure of uncleaved into cleaved rock. He alleges "that cleaved limestones possess no crystalline polarity," and that in place of crystallisation producing slaty cleavage, it has a contrary tendency, and, when perfect and complete, obliterates it altogether. Mr Sorby conceives that the absolute condensation of the slate-rocks amounts, upon an average, to about one-half of their original volume.‖ This condensation he ascribes to the forcing together of the particles, and the filling up of their interstices by pressure perpendicular to the cleavage, and partly by elongation in the direction of the cleavage dip.

---

* LYELL'S *Manual,* p. 610.

† Report, British Association, Cork, 1843.

‡ *Quarterly Jour. Geol.,* viii. 87.

§ See *Geological Observations on South America.*

‖ LYELL, p. 612.

Mr David Forbes,[*] writing upon foliation in rocks, leans to the conclusion that foliation is a distinct phenomenon from cleavage, and that the causes producing them were also distinct. He refers the foliation to chemical action, the cleavage to mechanical pressure. He admits that the planes of foliation and those of cleavage are often parallel to one another.[†] But the parallelism of the foliation to the cleavage he ascribes to a previously induced cleavage-structure facilitating crystalline lamination in its own planes.

He supposes foliation to have resulted from a chemical action combined with a simultaneous arranging molecular force, developed at heats below the semi-fusion of the mass ; also that the arrangement of foliation is often due to the proximity of igneous rocks, and tends to follow the direction of any lines in the rocks where the cleavage stratification, *or striæ of fusion*, follow preferably those lines offering least resistance.

Examination of the Prevailing Theories of Cleavage and Foliation.—From the theory of the origin of cleavage by mechanical compression exerted perpendicularly to the cleavage-planes, as adopted by Mr Sharpe, Mr Sorby, Mr David Forbes, and other geologists, I am constrained to dissent, and upon the following grounds :—

1. It has been already shown, in the general description of the phenomena of cleavage, that this tendency of fissuration is stronger and weaker in alternate closely contiguous planes, and is not diffused equally, even in the one direction, through the mass. Now it is impossible to conceive how a purely mechanical compression could have occasioned a regular alternation of greater and less condensation of particles, all equally free to move and adjust themselves into positions of statical equilibrium, and all equally subjected to the same amount of force. The well-known law of a *quaquaversal* tension of fluids is manifestly applicable to partially soft and flexible rocky matter, if we are to impute to this an actual rotation of its parts, such as the mechanical theory assumes ; and I cannot see why one uniform condition of aggregation should not be the result.

In partially metamorphosed strata, imbedding nodules of flint or chert, we not unfrequently find the ovoidal lumps all arranged with their larger diameters set in the direction of the cleavage, and not in that of the stratification. An instance of this structure has been already alluded to in the description of Fox Hill, near the Delaware Water-Gap (see Vol. I. p. 285.)

It is impossible to conceive how these large, flattish, ovoidal flints could have had this direction impressed upon them by any mere mechanical force. All geologists admit the concretionary origin of such nodules. Now, on the hypothesis of the derivation of cleavage from pressure, if they could only have concreted *before* the cleavage structure was imparted to the stratum enclosing them, their wider diameters must have been originally parallel with the bedding. If so, the nodules could only have acquired their new position of parallelism to the cleavage which is transverse to this bedding, by either a bodily rotation, or a plastic compression of their substance, despite their intense rigidity of cohesion. Imbedded in a material softer than themselves, it is obvious that neither of these changes could take place. It is difficult, moreover, to imagine how any mere compression or rotation of the individual nodules could have ranked them into new planes transverse to the layers in which they were originally disposed. We know that silicious nodules, like the lumps of clay ironstone of the coal shales, and indeed all similar concretions, are distributed in layers or courses, these layers marking the horizons where the material was originally in excess ; but once formed, they could not shift into new attitudes without a corresponding displacement of the strata imbedding them. But supposing, for the sake of argument, the nodules to have been from the first not arranged in strata, but promiscuously scattered, no transverse pressure could even then squeeze them into parallel and distant courses or strata.

2. In the second place, it assigns no reason for the presence of cleavage-planes in fine-grained argillaceous and calcareous rocks, and their absence in silicious ones, both fine-grained and coarse, even when the two classes alternate with each other in intimate parallel contact, where they must have been exposed to precisely the same pressure, both in direction and in amount. In other words, there is no relation discoverable between the known susceptibility of different materials to cleavage, and their susceptibility to compression. But, on the other hand, some of the most compressible are the least subject to this peculiar structure. The different susceptibilities of different kinds of mineral matter to molecular polarity is, I conceive, the true explanation of this marked contrast in rocks.

3. Another quite conclusive objection, I conceive, to the pressure theory of cleavage is, that it fails to show how the cleavage-traversed strata can have received the pressure in one constant direction, and under an equalised intensity, through all the contortions and bendings which we know they must have possessed before cleavage was imparted to them. It is obvious that no mechanical pressure, come from what quarter it might, could transmit itself uniformly through convex and concave curves, through bodies of rock placed edgewise and flatwise towards it ; but, on the contrary, dynamic considerations must convince us that the resultants of such a pressure would be as various in their directions within the mass, as the ever-changing planes of the corrugated stratification. Not only would the posture of the strata at any point next the quarter of the primary pressure influence the form and direction of the resultant planes of pressure at that point, but the differences in pliability of the different layers compressed would greatly modify them. In other words, while the dip of the cleavage-planes within even wide limits is usually remarkably constant, whatever the contortions of the strata, any pressure

---

[*] See his Paper—*Quarterly Journal Geological Society*, 1855.

[†] See his Paper for a good figure of deflection of cleavage and foliation in the margin of a vein of quartz.

transmitted through these contortions must be as various, in different portions of the flexures, as the innumerable resultants produced by the ever-varying resistances and the pressure combined.

4. A like difficulty opposes itself to the pressure theory, in the constancy of the direction of the elongation or stretching of the mass in the line of its cleavage dip. This extension, well expressed by Professor Phillips as a "creeping movement of the particles," seen not only in the fibrous grain of cleavage-slates, but in the distortion of imbedded fossils, and of the whole substance of the rock indeed—ascribed to mere compression by the authors above cited, but attributable, I think, to an actual molecular movement of the mass, in obedience to crystallising polar forces—is so equally graduated in amount, and so wonderfully constant in direction (never deviating much from the line of dip of the cleavage-plane), that it could never have acquired this constancy from a merely lateral mechanical force, liable to infinite modification, in both of these respects, by the continually varying resistances consequent on the contortions of the beds.

5. A further objection lies against the pressure theory, in the contradiction it offers between the direction which it assumes the compression to have come from, and the direction in which we can demonstrate the strata to have been actually pressed and moved. In every district of plicated and undulated strata, it can be shown, from the shape of the waves, from the declension in their curvature and height, from their mutual recession, from abatement in all the metamorphic signs of igneous action, and, finally, from the direction of the great planes of fracture in the crust, that the movement and pressure were upward and forward from the quarter of chief crust-disturbance. Now it is nearly at right angles to this established direction of the forces, that the hypothesis I am reviewing assumes a pressure to have been applied to produce the cleavage. The planes of fissuration dipping inward towards the igneous side of the belt, any cleavage-producing pressure to be perpendicular to these planes, as the theory alleges it to have been, must have come either from a point or line elevated at least 45° above the earth's surface, or else from a point or region far below the earth's crust on the opposite side, or in the quarter where the cleavage is absent, or is invariably the least distinct, and where the flexures of the strata, and all other evidences of crust-movement, are vanishing. This is, I conceive, a dynamic dilemma in which the compression theory finds itself,—either to make the force emanate from a quarter external to the crust entirely, or from just that quarter where we have the fullest evidence of the absence of any force at all. Thus, if the theory is applied to explain the South-dipping cleavage of the Northern flank of the Alps, it implies either that the pressure came, not from within the crust below the crest of the chain, but from some point in the air high over the summits of the mountains, or else from some deep-seated subterranean region far to the North of the Alps, under the undisturbed planes of Northern Switzerland or Germany. In the case of the Appalachians, it requires that the pressure should have come, not from under the convulsed and ruptured region of the Atlantic slope, but from some high aerial point above this, or else from a spot diametric to it, deep under the plains of the Western States, where neither cleavage, metamorphism of any kind, nor undulations of the strata exist, to indicate the former presence of any compressing force at all.—(See *Sections of the Appalachians and Alps*, figs. 706 and 714.)

6. Besides this general difficulty, I have a special one to offer connected with the laws of cleavage dip. This applies not only to the theoretical generalisation of Mr Daniel Sharpe respecting the relations of the cleavage-planes to each other in different parts of a zone of slaty cleavage, but to the observations upon which his generalisation has been built. His sections of the cleavage in North Wales and elsewhere represent it as perpendicular or steepest in the belts of maximum igneous action, and flattest in the regions most remote from these, where he places the anticlinal axes of his cleavage-curves. Now, just the reverse of this steepening of the cleavage planes towards the regions of chief metamorphism will be found to be the real law of gradation in the Appalachians, the Alps, and the district of the Ardennes and Southern Belgium. Obedient to a law already explained, the cleavage dip, following the dip of the axis-planes of the flexures, is not most but *least* inclined in the districts most convulsed, and grows progressively steeper as we advance across the undulations to the districts of minimum disturbance. In the Alps the plications lie flattest next the high central crests of the chain, and there the cleavage dip is often at a very low angle; but receding towards the plain of Switzerland, where the theoretical view requires that it should be flatter, it is really steeper, and even approaches to perpendicularity: and precisely analogous is the gradation when we cross the Appalachians from S.E. to N.W. Generalising the dips of the cleavage-planes on both sides of a double belt of flexures like that of the Alps, and excluding the central crests, where the jointage of the igneous rocks and the cleavage structure impressed by them is more vertical, the real curve of dip for the whole zone will be found to be a *synclinal* one, and not the two halves of two anticlinals, the generating axes of which are far outside the chain—one in the plain of Switzerland, the other in the plain of Northern Italy.

I am much gratified to find that my objections to the mechanical theory of cleavage find support in the able writings of Professor Sedgwick, who, in a note in his "Synopsis," states several cogent reasons for rejecting the hypothesis. While some of my own objections are but an expansion of those presented by this eminent geologist, others are independent of his, growing out of my own observations. This accordance gives me additional confidence in the soundness of the generalisations upon which they rest.

THEORETICAL VIEWS.

Theory of the Flexure and Elevation of Undulated Strata.—The wave-like structure of the Appalachians and other undulated zones has been attributed by the Author and his brother, Prof. W. B. Rogers, in their communications to the American Association in 1842, and to the British Association in the same year, to an actual undulation of the supposed flexible crust of the earth, exerted in parallel lines, and propagated in the manner of a horizontal pulsation from the liquid interior of the globe. We suppose the strata of such a region to have been subjected to excessive upward tension, arising from the expansion of molten matter and gaseous vapours, the tension relieved by linear fissures, through which much elastic vapour escaped, the sudden release of pressure adjacent to the lines of fracture producing violent pulsations on the surface of the liquid below. This oscillating movement in the fluid mass beneath would communicate a series of temporary flexures to the overlying crust, and these flexures would be rendered permanent (or keyed into the forms they present) by the *intrusion* of molten matter. If, during this oscillation, we conceive the whole heaving tract to have been shoved (or floated) bodily forward in the direction of the advancing waves, the union of this tangential with the vertical wave-like movement will explain the peculiar steepening of the front side of each flexure, while a repetition of similar operations will account for the folding under, or inversion, visible in the more compressed districts. We think that no purely upward or vertical force, exerted either simultaneously or successively along parallel lines, could produce a series of symmetrical flexures, and that a tangential pressure, unaccompanied by a vertical force, would result only in an imperceptible bulging of the whole region, or an irregular plication dependent on local inequalities in the amount of the resistance. The alternate upward and downward movement necessary to enable a tangential force to bend the strata into a series of regular parallel subsiding flexures has been, we conceive, of the nature of a pulsation, such as would arise from a succession of actual waves rolling in a given direction beneath the earth's crust. It is difficult to account for the phenomena by any hypothesis of a gradual prolonged pressure exerted either vertically or horizontally. And, further, the formation of the grand yet simple flexures so frequently met with cannot be explained by a *repetition* of feeble tangential movements, since these could not successively accord either in their direction or in their amount; nor can it by a repetition of merely vertical pressures, for it is impossible to suppose that these could, without some undulating action, shift their positions through a series of symmetrically-disposed parallel lines. We find it equally impossible to understand how, if feeble and often repeated, these vertical pressures should always return to the same lines to produce the conspicuous flexures we behold. The oscillations of the crust to which the undulations of the strata are attributed have been, we conceive, of the nature of the earthquakes of the present day. Earthquakes consist, as we think we have demonstrated, of a true pulsation of the flexible crust of the globe, propelled in parallel low waves of great length and amplitude with prodigious velocity, from lines of fracture, either conspicuous volcanic axes, or half-concealed deep-seated fissures, in the outer envelope of the planet.

Theory of Cleavage Structure.—Concerning the cause of slaty cleavage, I have adopted the explanation originally proposed by Professor Sedgwick, that it is due to crystalline or polar forces, acting simultaneously and somewhat uniformly in given directions on large masses having a homogeneous composition. And following up the further suggestion in extension of this idea, ingeniously proposed by Sir John Herschel, that this molecular force was of the nature of an incipient crystallisation, and has been developed in the particles, by their being heated to a point at which they could begin to move among themselves, or upon their own axes, I have endeavoured to show, that whether the cleavage-traversed strata have been much disturbed or not, the cleavage planes invariably approximate to parallelism with those great planes in the crust which appear to have been the planes of maximum temperature. It has been already stated that the cleavage dip is parallel to the average dip of the anticlinal and synclinal axis-planes, or those bisecting the flexures. Now, it is easy to prove that these axis-planes, and the inverted parts of the flexures, are just those portions where the greatest wrenching, fissuring, and opening of the strata must have occurred, and where the highly-heated pent-up volcanic steam and gases, and liquid mineral matter, must have found their chief channels upwards to the surface.

Without attempting at present to apply this doctrine in detail, I will content myself with reviving a suggestion I formerly put forth, that every plicated belt of strata may be looked upon as having, from the causes here adverted to, become traversed, at the time of their folding and metamorphism, by a series of alternate hotter and cooler parallel planes or zones of temperature, arranged in oblique dip, coincident approximately with the axis-planes of the flexures. These planes or surfaces of high temperature we may suppose to have acted to polarise the particles in corresponding planes, by transmitting through the half-softened mass a succession of parallel waves of heat, stimulating the molecular crystallising forces which are ever resident in mineral matter, and which only await there the quickening influence of such a temperature to develope in the mass special lines and surfaces of maximum and minimum cohesion.

This conception, that the surfaces or planes of crystalline lamination, including cleavage, which is but a lower grade of the same species of molecular metamorphism, are approximately parallel to the surfaces of the waves of temperature which have moved through the strata, is not a mere hypothetical speculation, but an induction at which I have arrived from a comparison of many observations of my own with phenomena well recorded by the ablest geologists. Nearly all observers who have noted the influence of igneous dykes and veins upon the strata adjoining them, both in mines and external exposures, have seen a more or less distinct lamination or cleavage adjoining the walls of the once heated mineral matter, and have been struck by its very general parallelism to the surface or the axis of the vein. Cases occur in strata of all ages, and are frequently brought to light in coal-fields, when nearly vertical dykes cutting low-dipping or horizontal shales, susceptible of the cleavage metamorphism, have occasioned in the latter a true cleavage perpendicular to the stratification, or parallel, more strictly speaking, with the once hot surface of the intrusive rock.

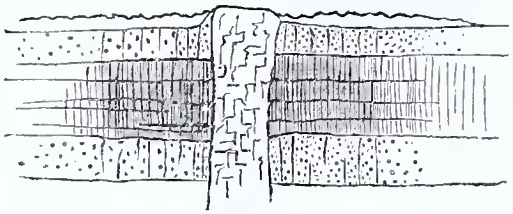
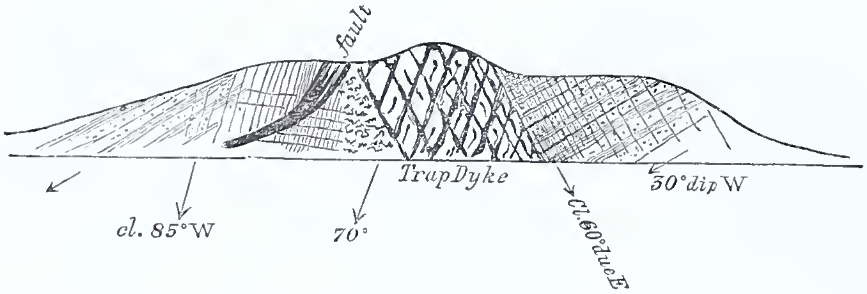


FIG. 718.—Cleavage in Red Shale, caused by a Trap-dyke parallel to its walls, near New Hope, Pennsylvania.*

Other instances are often presented of masses of superincumbent trap-rock, baking and altering argillaceous and other strata, in which a like law of parallelism of the cleavage to the heat-imparting surface of the molten matter is shown in the horizontality of the cleavage-planes, whatever be the dip of the strata. Numerous examples can be cited, where one igneous dyke cutting another, or traversing a mass of earlier Plutonic rock, produces in the latter a crystalline grain, amounting to a sort of cleavage, adjoining the bounding surfaces of the newer injection, and in planes invariably parallel, or nearly so, to the walls of the fissure. A similar fact of the occurrence of a cleavage parallel to the walls of highly-heated fissures, may be seen in the faults and great dislocations which traverse some parts of the anthracite coal-basins of Pennsylvania. Here the greatly indurated argillaceous shales, and even sometimes the coal itself, display a cleavage-structure invariably parallel to the general plane of the fracture. Such fissures would be the natural channels through which heated volcanic steam would ascend from the interior, and the action of this upon the strata most susceptible of cleavage would be precisely analogous to that of a molten dyke, in transmitting a wave of heat perpendicular to its surface, partially softening and half polarising the matter as it passed.

FIG. 719.—Cleavage superinducued by a Trap-dyke in Red Argillaceous Sandstone of Jurassic (?) age, W. of Gettysburg, Pennsylvania.



GENERAL RESUMÉ.

1. *Wave-like form of all belts of uplifted strata.*

    a. It is a general fact that strata dip in curved and not in straight planes.

    b. Wherever wide areas of the crust have been elevated or depressed from the level at which their strata were deposited, these strata will be found, except where their dip is disordered by crust-dislocations, to constitute, in their varying angles of dip, one or more wide regular curves.

2. *Parallelism of crust-undulations.*

    a. It is another general fact, that these undulations of the strata are in the form of long parallel waves, resembling much those great continuous billows called in dynamics "waves of translation," and by seamen "rollers."

3. *Relations of flexures.*

    a. Parallelism of the waves to the general trend of the part of the mountain system to which they belong, and especially to its chief igneous axis.

    b. Parallelism of flexures extends not only to adjacent individual waves, but to contiguous groups, and is as true of curvilinear as of straight ones.

---

* There is a similar instance cited by Professor Phillips, I think, in his *Geology of Yorkshire.*

c. The waves of the strata are generally of two or three grades of magnitude, as respects their length, height, and amplitude, and while those of the same grade are parallel, the different grades are not necessarily so.

4. *Laws of form and gradation of waves.*

There are three characteristic forms of crust-waves : symmetrical flexures, equally steep on the two slopes ; normal flexures, curving more rapidly on one side than on the other ; and folded flexures, or those with a doubling under of their more incurved slopes, and among which the steepest slopes are generally directed to the same quarter.

The geometric planes bisecting the anticlinal and synclinal bends of the strata, here called axis-planes, are nearly perpendicular in the symmetrical waves, but inclined in the other two classes, dipping at the lowest angle in the folded flexures. In many belts the plication is such as to amount to parallelism of all the inverted to the uninverted sides of the waves.

Some waves are straight, some curvilinear and crescent-shaped, and many of them extremely regular, changing their trend 40° or even 50°. The curvilinear ones convex *from* the disturbed sides of the zones, are generally more regular than those which are convex *towards* them.

5. *Gradations in flexures.*

a. In all undulated zones, the succession, starting from the most disturbed side, is invariably from the folded waves to the unequally sloping or normal ones, and from these to the equally sloping or symmetrical.

b. The waves grow progressively wider apart, or increase their amplitude, as they pass from the folded to the equally sloping form.

c. The waves progressively flatten down as they recede from the folded side of the belt.

d. The axis-planes of the flexures of any great undulated zone all incline towards the same quarter, that of maximum disturbance, the angle of inclination being less the nearer the wave or plication is to that side.

6. *Fractures or faults.*

In undulated districts, the dislocations are of two kinds : (1.) Numerous short ones, transverse to the strike of the axes, and shifting the strata to but a trivial extent ; (2.) longitudinal ones, fewer in number, of great length, and producing often great displacement.

The longitudinal faults very generally dip towards the same quarter as the axis-planes ; indeed, they are either ruptures in the axis-planes of the flexures or in the steep or inverted sides of the waves.

This slanting of the plane of dislocation parallel with the leaning of the wave, causes the newer or upper formations, on the inverted side, to dip under the older or lower on the uninverted side of the flexure or the fault, for almost always the uninverted side has been shoved forward and upward across the inverted.

Some undulated belts are single, or have all the axis-planes of the flexures dipping to one quarter, as the Appalachians and the zone of Southern Belgium. Others are double, or consist of two such zones, both dipping inwards towards one central line of chief igneous disturbance, and these latter present in this inward general leaning a fan-like structure, as in the Alps.

7. *Phenomena of slaty cleavage.*

a. The cleavage dip is independent of the dip of the strata; and still more remarkably, the cleavage-planes of a district are generally parallel to the axis-planes of its flexures.

b. Immediately within the anticlinal and synclinal axes, the cleavage-planes depart from their parallelism to the axis-planes and dip inwards towards them in a kind of fan-like arrangement.

c. The cleavage is only present where the rocks consist of certain materials, abounding most where they are most argillaceous and of finest texture, disappearing and reappearing with changes in the composition of the strata, even where these closely alternate.

d. In such groups of alternating cleavable and non-cleavable beds the cleavage-planes curve from the normal dip they possess, to approach to a parallelism with the planes of separation of the strata as they near their surfaces.

e. The cleavage susceptibility is alternately greater and less in closely-adjacent parallel planes. The ribbon structure of glaciers is probably analogous to the cleavage structure of argillaceous rocks.

8. *Foliation.*

In districts of crystalline, metamorphic, or gneissic strata, not much disturbed or corrugated, the foliation generally coincides with the stratification. In regions much corrugated, the foliation, on the contrary, is often at a steep angle to the stratification, and shows a tendency to dip, as cleavage does, parallel to the axis-planes of the flexures. Generally the direction of the foliation appears to conform to that which the waves of heat metamorphosing the rocks would take in slowly flowing through them.

9. *Theories of elevation.*

a. A common hypothesis of the cause of the elevation of strata is that of a wedge-like intrusion of melted matter. But this implies a function in semifluid or fluid matter incompatible with the dynamic properties of liquids. Some force must have first cracked the strata before the molten rock could insert itself. Veins and dykes tapering upward do not belong to lines of anticlinal elevation, where geologists so frequently indicate them, but to synclinals or concave curves.

b. The kindred idea of the intrusion of igneous rocks in solid wedges separating and lifting the crust is also at variance with sound mechanical laws. To exert this lifting and thrusting force, the assumed wedges must have moved freely through the fissures they fill; but we see no proofs of discontinuity between the igneous and stratified rocks, but only evidences of the closest cohesion.

c. A modified view of the wedging up of the flexible strata, conceives them to have been simply carried up by the lifting of the igneous nucleus. Such movements have no doubt occurred, and have served to steepen the strata leaning against the igneous rocks, but they cannot have corrugated the strata, which would be rather stretched than compressed by the elevation.

d. The hypothesis of a simple upward pressure at points or lines in the crust, which does not include an explanation of the wave structure of disturbed districts, cannot be a true theory; it must show how the pressures have shifted to new and parallel lines, and lines constantly receding; and also show why, if the linear pressures were simultaneous, they should not have produced a wide general arching, rather than a series of contiguous sharp waves.

e. The hypothesis of the origin of flexures from a sinking of the ground by removal of volcanic matter beneath it, supplies no explanation of the origin of zones of regular undulations. The sinking of any weak segment of the earth's crust might produce a trivial general warping, but not a belt of waves.

f. The hypothesis of a simple lateral or horizontal compression, illustrated by the folding of layers of any flexible material squeezed edgewise, and kept down by a weight, is open to the objection that this mode of folding offers no true analogy to the great symmetrical parallel flexures met with in nature. Flexures thus artificially produced, show neither the forms nor the gradations characteristic of the crust-waves. A purely tangential force would cause the district within its influence to bulge slightly upward, but not to corrugate into regular undulations, and it fails to find an origin for a pressure in the direction assumed.

10. *Theories of cleavage and foliation.*

a. The prevailing notions of geologists respecting the origin of cleavage and foliation are, on the one hand, that they have been produced by different intensities of molecular crystallising polarities, excited by heat operating in a definite direction; on the other hand, that they have been caused by mechanical compression of the strata applied perpendicularly to the cleavage and foliation planes.

b. One main objection to the pressure hypothesis is, that it does not account for the existence of planes of alternately stronger and weaker cohesion.

c. Another difficulty is, that it fails to explain the dependence of cleavage upon the texture of the rock, especially its chemical nature, and particularly where cleavable and non-cleavable strata alternate in close contact.

d. A third important objection exists in the dynamic difficulty, that the cleavage is nearly parallel and constant in its dip, despite the inequalities which a lateral pressure should undergo in its transmission through all the contortions and various postures prevailing in the strata.

e. A fourth difficulty, analogous to the last, is presented by the constancy in the amount and direction of the elongation or creep of the cleavage rocks in the direction of their cleavage dip; a constancy not compatible with the ever-varying tension which the flexures and bendings of the strata would occasion.

f. An additional objection presents itself, in the direction of the pressure implied by the theory, which, assuming the force to have been perpendicular to the cleavage-planes, implies it to have come either from a source above the earth's surface, on the side towards which the cleavage-planes are dipping, or from a source far beneath the crust, in that quarter where invariably the cleavage and all other symptoms of metamorphism are least abundant, or entirely wanting.

g. Still another important objection arises, in the contradiction exhibited between the law of gradation in the steepening of the cleavage dip demanded by the theory, or one form of it, and the actual law of the gradation of this dip witnessed in all districts of regular crust-plications. The theory represents the cleavage dip as growing progressively steeper the nearer it is to the lines of greatest igneous action ; the facts in nature show that the cleavage, the foliation, and the axis-planes of the flexures, with which these are approximately parallel, grow progressively steeper the farther they recede from those lines of maximum energy.

Concluding theoretical views.

The wave-like structure of undulated belts of the earth's crust is attributed to an actual pulsation in the fluid matter beneath the crust, propagated in the manner of great waves of translation from enormous ruptures occasioned by the tension of elastic matter. The forms of the waves, the close plication of the strata, and the permanent bracing of the flexures, are ascribed to the combination of an undulating and a tangential movement, accompanied by an injection of igneous veins and dykes into the rents occasioned by the bendings.

This oscillation of the crust, producing an actual floating forward of the rocky part, has been, it is conceived, of the nature of that pulsation which attends all great earthquakes at the present day.

11. *Theory of Cleavage.*

The cleavage-planes having been shown to be parallel to the axis-planes of the flexures, and locally to the planes of the great faults, and these being obviously the belts of maximum temperature in a plicated district, it is suggested that both cleavage and foliation are due to the parallel transmission of planes or waves of heat, awakening the molecular forces, and determining their direction.

CLASSIFICATION OF THE SEVERAL TYPES OF OROGRAPHIC STRUCTURE VISIBLE IN THE APPALACHIANS AND OTHER UNDULATED MOUNTAIN-CHAINS.

FEATURES OF GENERAL EROSION.

I.—EROSION OF HORIZONTAL STRATA.

Various circumstances have influenced the erosion of even horizontal or approximately horizontal strata, and consequently the features of their denudation are somewhat diversified. The smaller or more local ones will be considered under a separate head, and I shall here allude only to the wider and more conspicuous ones. These belong chiefly to the edges or level outcrops of the strata; for where the deposits of a region are very nearly horizontal, no striking changes of slope or scenery on a large scale can arise on the level plain or surface of the formations, but only where their edges are exposed. This exposure may result either from a descent in the surface of the country intersecting strata absolutely level, or from a slight inclination or dip in the strata themselves, the ground remaining at one general height above the sea; or it may arise from both combined—a sloping surface and a gentle dip.

The prominent phenomena of wide erosion under these conditions depend on a diversity in the cohesion of the strata, enabling some of the beds, when cut into and exposed, to resist the destruction to which others readily yield. The essential structure resulting from a general and deeply-penetrating erosion, of an alternating series of firm and incohering beds, is that of a succession of terraces, or of plains terminating by abrupt slopes or escarpments—the width of the terraces and the height and contour of the escarpments being controlled by the relative thicknesses of the strata, by their departure from horizontality, and by the greater or less general slope of the country. Wherever the stratification is very nearly level, and the softer groups of strata much exceed the harder shelf-forming ones in thickness, the plains are broad between the successive escarpments, unless, indeed, a deep valley or denuded plain cuts off the whole series, and gives it the external structure of an elevated terraced plateau. Even in this case, the terraces which bound the plateau are comparatively wide. If, on the contrary, the softer members are thin in proportion to the harder, and the other conditions are the same, the individual terraces are narrow; and if the entire series stands out as a plateau above a lower adjacent country, its general escarpment is necessarily steeper.

I proceed to illustrate the several varieties of Terraces and Terraced Plains.

a. *Where each principal Stratum is Homogeneous as respects its Hardness or Softness.*

Not only is a certain extent of contrast in hardness and softness in the alternating strata essential for the production of prominent features of escarpment and of level terrace, but a very considerable degree of uniformity in composition throughout each member is no less important. Where these two conditions prevail in a high degree, the surface of each terrace or plain is level and uniform, and its edge or escarpment precipitous and bold; but where the individual strata are neither homogeneous in themselves nor much unlike each other in degree of hardness or cohesion of their particles, the surface will be uneven, and will form a sloping plain, and their edges will produce only slanting and more or less faintly-benched hill-sides.

1. *Plateaus with Simple Escarpments.*—These occur where there are but two strata, and the upper one is much the harder. The greater or less degree of precipitousness in the edge of the plateau or terrace will depend, as we have seen, upon both the relations of thickness and of hardness in the two masses. But peculiarities of rock-structure, such as the presence or absence of great joints, likewise exert an important influence in deciding the steepness and form of the escarpment. We must also infer that, all these elements being the same, there will arise a marked diversity in ruggedness or softness of outline, as the stratum may have been cut by violently-moving heavy currents of water, or may have been more gently washed and worn by thin and feeble ones.

The annexed section of the cliffs of the gorge of the Niagara River at and below the cataract will illustrate the escarpments of this class, where jointage in the upper rock conspires with its greatly superior hardness under erosion, to impart the character of a cliff or precipice.—(Fig. 720.)

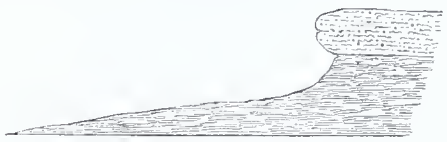


FIG. 720.—Plateau with simple Escarpment, Shelf of Niagara.

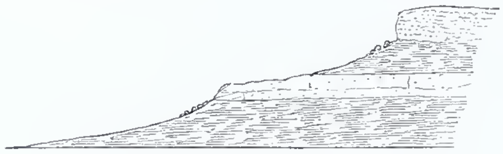


FIG. 721.—Plateau with complex Escarpment, Mountain-ridge, New York.

2. *Plateaus with Complex Escarpments.*—This feature in the edges of plateaus occurs where there are four or more chief beds alternating in composition and hardness, and where the lowest of the softer masses and the uppermost of the hardest are comparatively thick. Under these conditions the one or more subordinate terraces or shelves on the face of the slope cannot be wide, and the whole descent from the upper to the lower plain has the structure of two or three majestic steps or platforms.

Such are the features of the mountain ridge or terrace south of Lake Ontario in Western New York and Upper Canada, a profile of which is here appended.—(Fig. 721.)

3. *Terraced Plains.*—This structure of the surface arises from that continuation of nearly horizontal stratification, and nearly horizontal general denudation, which throws the outcrops of the several hard and soft strata very wide apart. The whole district is in this case a succession of very broad platforms. Such, in a general profile, is the entire plain of Western New York here illustrated (Fig. 722); and on a still grander scale, the great interior plain E. of the Rocky Mountains.

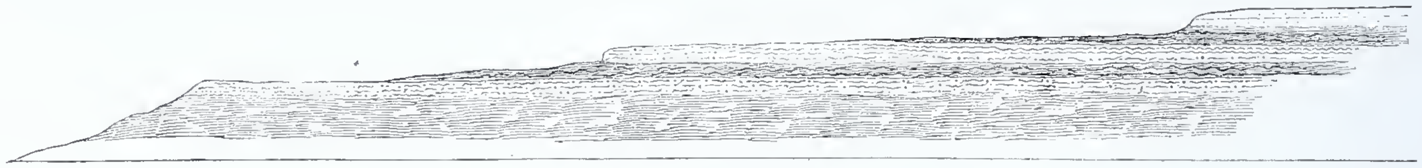


FIG. 722.—Terraced Plains.

b. *Where each separate Stratum is complex in Composition and Degree of Hardness.*

I have already shown that the want of homogeneousness in the chief members of a series of strata, and the consequent approximation of the several members to each other, is expressed in the profile of the surface by less conspicuous features, less precipitousness in the escarpments, less levelness in the terraces, and by more numerous but fainter benches on the edges of all the plateaus.

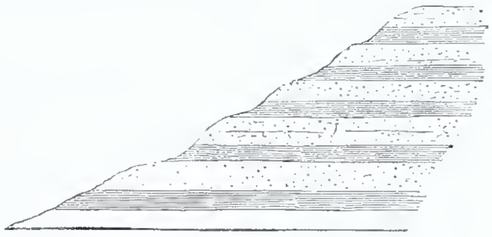


FIG. 723.—Plateau with terraced Escarpment, Pokono Mountain.

1. *Plateaus evenly benched in their Escarpments.* — This condition is presented wherever there exists a somewhat frequent and nearly uniform alternation in thickness and hardness of the eroded strata. If the firmer rocks are perpendicularly cleft by numerous parallel joints, and the softer ones are extremely soft or friable, the benches, though not necessarily wide, will be sharp and steep, and step-like; whereas, if the hard layers are coherent throughout, and the interposed ones somewhat firm, the benches will be rounded and obscure, and the whole escarpment an undulated inclined plain of steeper and gentler convex and concave slopes, like greatly-worn and rounded rocky stairs. Such in many places is the great sloping escarpment of the high table-land of the Pokono and Catskill mountains, and on a much smaller scale some of the plateau-like hills of horizontal Coal-measures in Western Pennsylvania. The Pokono Mountain, in its S.E. slope, is here indicated with its benches.—(Fig. 723.)

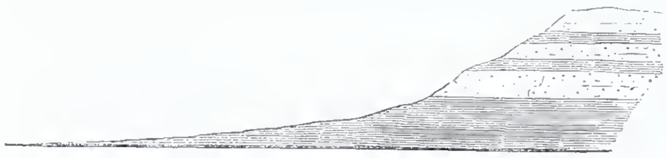


FIG. 724.—Plateau with upper Escarpment terraced, Alleghany Mountain, Pennsylvania.

2. *Plateaus benched only on their upper Escarpments.*—In those plateaus which are capped by an alternation of two or three hard and as many soft rocks, and underlaid by a thick stratum of less-enduring material, there will be seen an upper steep slope with benches, and below it a long, smooth, gently-spreading inclined plane. Such is the structure and the very usual profile of the S.E. front of the main table-land of the Alleghany Mountains in Pennsylvania.—(Fig. 724.)

3. *Plateaus terminating in precipitous Escarpments passing downwards into benched or terraced Slopes.*—In these instances the alternation is in the inferior or softer group of beds, and not in the upper harder one, as in the previous case; and the capping stratum must be massive and resisting. Where these conditions prevail, we have a terrace, or it may be a mountain plateau, bounded at its edge by a bold steep precipice, rising from a long inclined escarpment, benched more or less distinctly or obscurely, as the nature of the lower alternating series may determine.

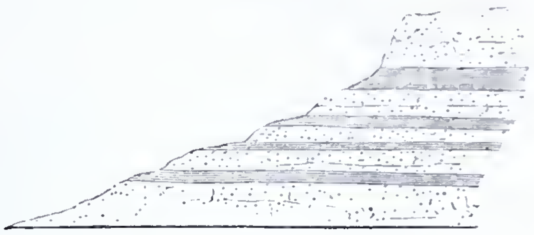


FIG. 725.—Plateau with lower escarped Slope terraced, Catskill Mountain.

This is a description of the structure of the external features of the more escarped front of the Catskill Mountain which faces the Hudson, and is characteristic likewise of certain portions of the edge of the Alleghany Mountain in Pennsylvania. (See Fig. 725.)

II.—FEATURES OF EROSION OF MONOCLINAL BELTS.

The erosion of tracts of strata dipping in one direction has led to a great variety of external features. Where the region denuded embraces crust-undulations of decided flexure, each monoclinal zone, whether wide or narrow, exhibits, of course, a gradation in the steepness of its dips, varying in obedience to the nature of the flexures. The subordinate belts of dissimilarly-dipping rocks having presented their edges to the abrading waters at different angles, and therefore with unlike degrees of resisting strength, show unlike external outlines, even where the currents have been similar in force and direction, and where the relations of the subordinate strata to each other, in respect to their thicknesses, texture, and composition, have been nearly identical. But these two other sets of elements have themselves been very different in different districts; the waters have not wrought with the same weight and velocity, or in the same manner as to their currents and eddies, on all the rocks exposed to them; nor were the conditions of the several rocks, in all that influenced their unequal liabilities to erosion, equivalent in the different zones, or different belts of the same zone.

A study of the surface features of those districts of inclined strata which retain, as many do, the sculpturings left by the waters in all their freshness, and undisguised by any clothing of drift, will readily indicate—with a little reflection upon the modes of action of the eroding agent upon the variously-placed and constituted masses subjected to its wearing energies—the special influences of the several elements which have been here alluded to. It will show us that a general movement of the currents longitudinally with the outcrops of the inclined deposits, excavated the softer beds to a greater depth than the currents directed transversely; and it willindicate that the results produced where the strata were very steep, or merely presented their edges to the sheet of fluid and fragmentary matter which planed them down, were very different from those left upon more gently-dipping groups of hard and soft beds.

To enter elaborately into the consideration of all the modifications in the topography of monoclinal belts of strata, and to trace each to its causes, would take me beyond my present plan, which is chiefly to point out the existence of such modifications, and the general laws which control them. The principal features of erosion of evenly-dipping hard and soft rocks deserve, however, to be illustrated; and I proceed to exhibit them here.

a. *Where the Strata are alternately firmly and feebly cohering, and those of each Class are alike hard and soft.*

It is characteristic of formations thus composed to leave a surface after denudation more or less grooved and ridged along the outcrops, but approximately level in its wide features. The inclination of the rocks, and the difference in the hardness of the two sets, will determine, of course, the depth of the depressions or degree of ridging of the plain.

1. *Ridged or undulated Plains or wide Valleys.*—Here both the hard and soft rocks possess the average tenacity of these classes over a wide space. This feature is seen in many parts of the great Appalachian Valley.—(Fig. 726.)

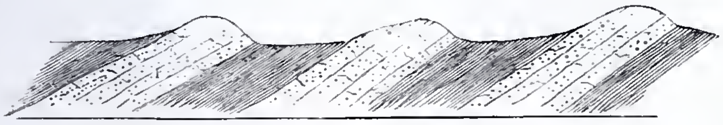


FIG. 726.—Ridged and grooved Plain.

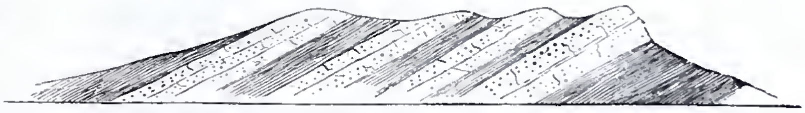


FIG. 727.—Ridged and grooved Table-land.

2. *Ridged and grooved Mountain-crests.*—Here the alternation of hard and soft rocks forms a general belt harder than the strata above and below them. The monoclinal mountains enclosing the Shamokin coal-basin display this structure in a marked degree.—(Fig. 727.)

b. *Where there are several Groups of Strata differing in their Degrees of Hardness.*

1. *Single-crested Monoclinal Ridges.*—These consist of three or more groups, and the central group is much harder than the flanking ones; and having been less cut away by the waters, stands forth as the higher part or crest of the edge. The Primal white sandstone and the Meridian sandstone frequently form ridges of this profile.—(Fig. 728.)

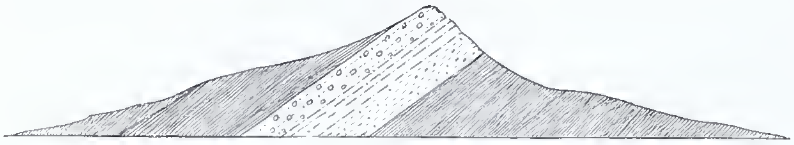


FIG. 728.—Single-crested Monoclinal Ridge.

2. *Double-crested Monoclinal Ridges.*—In these there are five or more groups, two of them hard formations, forming the crests; and between these a softer, making a high or crest valley; and outside, or below and above them, are still softer ones.—(Fig. 729.)

3. *Double Monoclinal Ridges with single Crest, but broad high Shoulder or Terrace.*—These are modified forms of the preceding class, consisting, like them, of five or more sets of strata, but having one of the harder groups considerably less resisting than the other. The most common and marked variety is where the lower hard rock has been the weaker of the two. Such is the very usual profile of the monoclinal ridges of the Levant series surrounding the Auroral limestone valley of Central Pennsylvania—(Fig. 730). The other variety is where the lower of the hard masses has been the firmer or more resisting one—(Fig. 731).

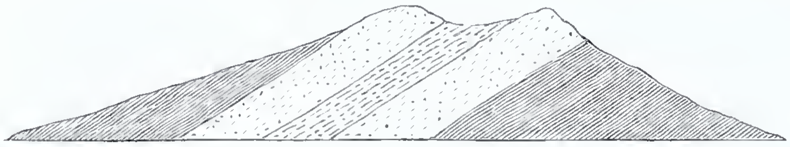


FIG. 729.—Double-crested Monoclinal Ridge.

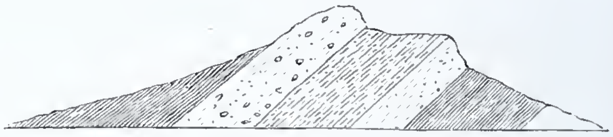


FIG. 730.—Double Monoclinal Ridge, with terrace on the back.

4. *Complex Monoclinal Ridges.*—These are composed of central harder rocks, and softer flanking ones—one, two, or all of the three series being complex, or containing an alternation of harder and softer beds.

There are several varieties dependent on the group or groups in which the marked alternation of hardness in the beds resides. Where it belongs to all three, the crest series and the lateral ones also, the mountain is then much terraced, being benched on its crest and on its sides.

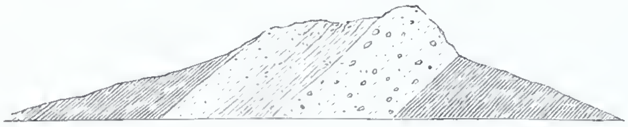


FIG. 731.—Double Monoclinal Ridge, with terrace on the front.

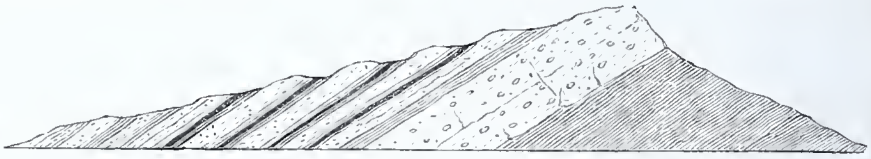


FIG. 732.—Complex Monoclinal Ridge.

A more common condition is where the middle group is homogeneous, and the upper or face side series is an alternating one. This is the structure of many of the monoclinal ridges bounding the anthracite coal-basins. A section is here presented.—(Fig. 732).

Another variety is exhibited where the middle or hardest set and the uppermost or face side strata are both of them complex or alternating groups. Ridges of this composition are benched or grooved alike on their summits and their dipward flanks. This structure is distinctive of the more Western anthracite valleys, and has its fullest development in the crests which enclose the Great Shamokin Basin. Here is a simple section.—(Fig. 733.)

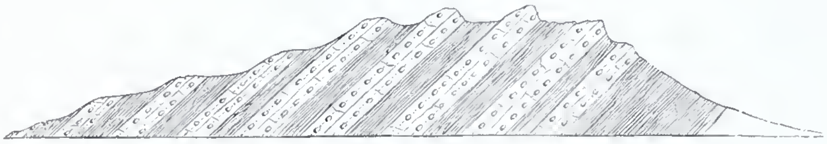


FIG. 733.—Complex Monoclinal Ridge.

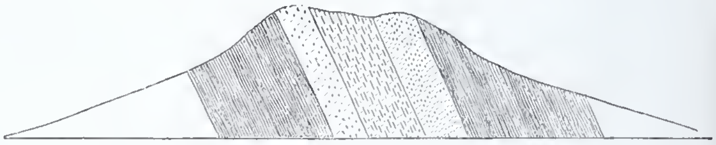


FIG. 734.—Monoclinal Ridge, a Profile of the Kittatinny Mountain, near the Susquehanna (strata inverted).

In all of these forms of monoclinal ridges, the relations of the different features to each other, the crests and slopes, terraces and benches, are more or less modified by every marked variation in the dip of the strata; and the deviations from the average orographic characters here given are the widest where the dip is inverted, or the rocks are overturned. This will be seen by comparing the annexed sketch of a ridge of Levant and Surgent strata inverted in their dip, as they sometimes are in Pennsylvania. The sketch (Fig. 734) shows the usual profile of the same rocks in their more natural or normal posture, which exhibit a double monoclinal ridge, with single crest and broad high shoulder.

All the long narrow monoclinal mountains are termed ridges in the United States, and so, indeed, are all elongated crests of whatever structure or precise shape; but in the Jura chain of Switzerland, the *crêts* are those only which have this monoclinal structure, and the anticlinal ridges are by the Swiss geologists called *voûtes*.

5. *Single-trenched Monoclinal Valleys.*—The conditions essential to valleys of this structure, which are extremely numerous in the Appalachian chain, are the superior softness or erosibility of the central or valley group over those

which adjoin it, and the absence of hard strata in the middle of it. All the anthracite basins are surrounded by valleys of this class.—(Fig. 735.)

6. *Double-trenched Monoclinal Valleys.*—In valleys having this profile there are at the least five groups or sets of strata, the two external ones of the five, superior enough in hardness to the rest to stand forth in ridges, and the central one of all, less firm than these, but harder than the valley-masses adjoining it. Upon the relative degrees of hardness and of thickness of all five masses, depend the minor variations of feature of every such belt.

This type of valley is very common inside of the anthracite basins between the ridges of the Levant and Vespertine rocks, the central ridge being of the Meridian sandstone.—(Fig. 736.)

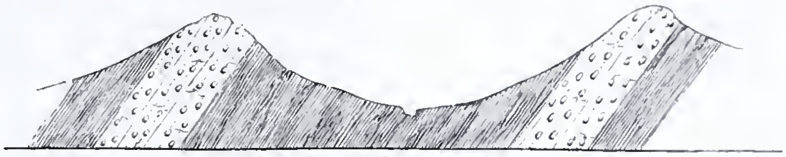


Fig. 735.—Simple Monoclinal Valley.

7. *Complex Monoclinal Valleys.*—These occur where the softer sets of strata are variously alternated with harder interposed formations. Where the alternation extends throughout the whole of the softer excavated groups, both the general bed of the valley and its slopes are more or less ridged and terraced.

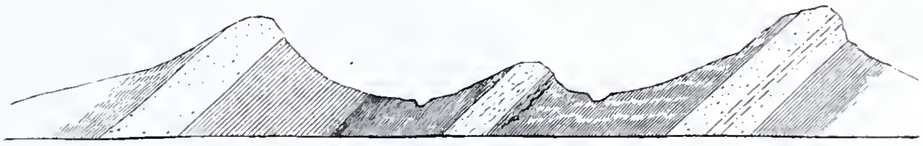


Fig. 736.—Double Monoclinal Valley.

Belts of this order are numerous on a small scale in all the more complex formations, especially in the wider monoclinal tracts of moderately-inclined anthracite Coal-measures. On a large scale they are perhaps most frequent in the Appalachians, along the S.E. base of the plateau of the Alleghany Mountain, the complex valley being between that ridge and the parallel crests of the Levant sandstones. The section (Fig. 737) represents this belt in Centre County, Pennsylvania.

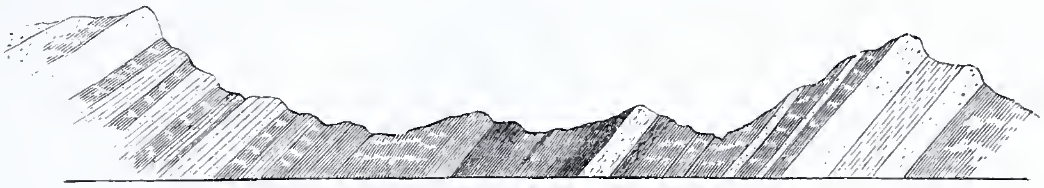


Fig. 737.—Complex Monoclinal Valley.

The relative prominence of the ridges and depth of the valleys of monoclinal structure is very closely connected with the conditions which controlled the energy of the longitudinally-acting portions of the excavating currents, as will clearly appear presently, when we are considering the mountain-notches, their origin and effects on the drainage.

In the United States, these long, narrow, monoclinal trenches between the mountains are called simply *valleys,* as are the wider anticlinal and synclinal and complexly-undulated ones, even where they have the relative width of plains. But in the Jura chain of Switzerland, the narrow elevated monoclinal and anticlinal valleys or troughs between the crests are designated *Combes.*

III.—FEATURES OF EROSION IN ANTICLINAL BELTS.

a. *Where the lowest Strata exposed, or those of the Anticlinal Axis or Summit of the Wave, are the hardest.*

1. *Single-crested Anticlinal Ridges.*—The conditions essential to this structure are a lower hard stratum and an upper softer one, bent into either a regular or an unsymmetrical anticlinal wave, so eroded on its summit as to expose the harder mass in a central crest.

Ridges of this composition and form are numerous in the Appalachians, and other undulated chains, though in their very simplest type, or without terraces on their sides, they are less common.

Some of the anticlinals of the Primal strata in South-eastern Pennsylvania are of this form. In the coal region they are always benched. A section of Montour's Ridge, towards its N.E. end, displays this simple form. Some of the spurs of the South Mountains also show it. The figure (738) represents the Primal white sandstone exposed in the crest, and Primal slates on the flanks.

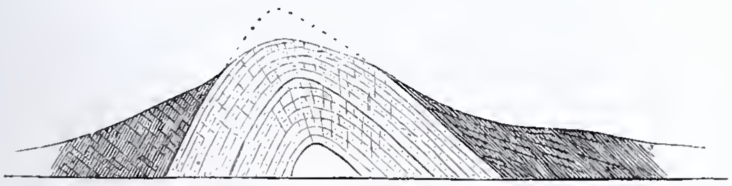


Fig. 738.—Single-crested Anticlinal Ridge.

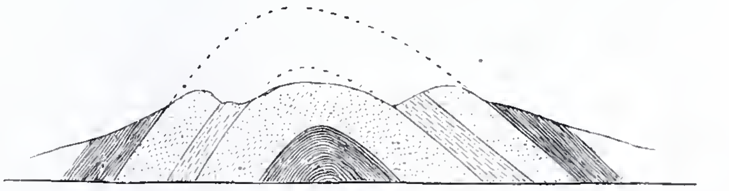


Fig. 739.—Triple-crested Anticlinal Ridge.

Every such interior anticlinal ridge or crest is in the language of the Swiss geologists, as applied to the Jura Chain, a *Voûte,* and the present simple type constitutes Thurman's *First Order* of anticlinal ridges.

2. *Triple-crested Anticlinal Ridges* (or ridges with a central anticlinal crest, and two lateral monoclinal crests or shoulders).—The ridges of this type, of which there occur some striking examples in the Appalachians, have been formed by the erosive action of the ancient waters on four separate sets of strata—two hard ones and two soft ones—the lowest of all, a hard formation, saddling the axis, and standing above or on a level with the two monoclinal crests of

the upper hard mass, while between these and the central crest the lowest soft deposit appears either in two high monoclinal valleys, or in a level wide terrace, the uppermost of the four rocks forming by its superior softness the two external flanks of the whole compound elevated belt.—(Fig. 739.)

A good instance of this structure is presented in Shade Mountain of Juniata and Union counties, Pennsylvania, of which an average section is here presented. Chestnut Ridge and Laurel Hill, of the bituminous coal region, are other instances.

The denuded anticlinals of this type occurring in the Jura chain, are those ranked by Thurman as his *Second Order* of upheavals.

b. *Where the lowest Strata exposed along the Anticlinal Axis are softer than those resting on them.*

1. *Simple Valleys of Elevation* (or double-crested ridges, with anticlinal valleys or plateaus enclosed between them).—The anticlinal belts of this structure are of two classes—those which belong to mountain-ridges, and those which are central parts of wider plains or valleys; but the present section is devoted to those which are features of ridges.

The essentials to this form of anticlinal ridge are, the exposure by erosion of three sets of strata, a lower soft group, a middle hard one, and an upper soft one again. The lower mass saddles the axis, the denudation not penetrating through it, but the harder middle rock is longitudinally cut away at the crest, and left in two parallel crests embracing a high valley between them, by the wearing of the inferior softer one, and the previous removal of the overlying soft group.

Such is a very frequent feature, on a small scale, in the Appalachians. It occurs in the anthracite coal-fields; is seen in belts of Pre-meridian limestone between ridges of Meridian sandstone, and in other valley-rocks; but it is more conspicuously displayed on a larger scale in the long regular anticlinals of the Levant sandstones S.W. of the Susquehanna. The best example on the large scale is the Blue Ridge of the Juniata, here presented in profile.—(Fig. 740).

The terminal portions of many of the other Levant sandstone ridges present a structure identical with this.

These high anticlinal valleys, no less than the elevated monoclinal ones, are termed *Combes* in the Jura.

2. *Complex Valleys of Elevation.*—These are valleys formed by a deep denudation in the back or summit of an anticlinal wave, exposing at least *five* sets of strata, the lowest being soft and cut into, but not cut through. The second, a hard formation, longitudinally intersected over the arch, outcrops in two parallel crests, or it may be in two shoulders of high terraces; the third a softer mass, likewise of course cut through, forms these terraces, or else two high monoclinal valleys, by its outcrops; while the fourth, a second hard material, still further sundered, forms two other crests exterior to the terraces or high valleys, and encloses the whole complex interior excavated tract, which, as the case may be, is either a triple valley, the central one a high "simple valley of elevation" divided by its two ridges from two high parallel monoclinal valleys, or a deep central anticlinal valley enclosed by two elevated terraces. In the Appalachian ranges, both in Pennsylvania S.W. of the Susquehanna, and in Virginia, the prevailing variety of this class of valleys is the deep central valley surrounded by a high terrace or platform. Such are the limestone valleys of Centre, Bedford, and other counties of the middle portions of the chain.

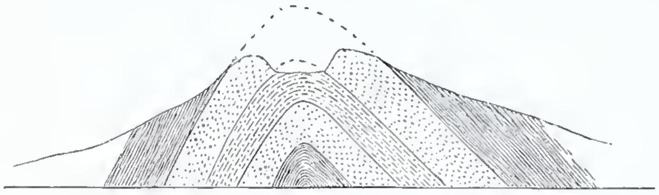


FIG. 740.—Double-crested Anticlinal Ridge, or simple Valley of Elevation.

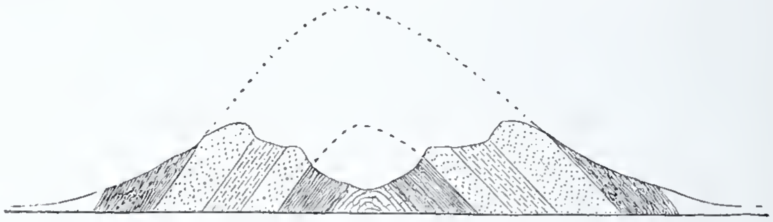


FIG. 741.—Complex Valley of Elevation.

The annexed section represents one of these—for example, Blacklog Mountain and Valley.—(Fig. 741.)

In the Jura chain of Switzerland both forms occur, but the most common seems to be that embracing four distinct ridges. The present type is Thurman's *Third Order* of upheavals.

It is obvious that the forms of eroded anticlinal belts will be more and more complex in proportion to the number of alternating hard and soft formations lifted and denuded in the back or arch of the wave; and that if seven, in place of the five such strata above represented, were embraced in the belt, there would be an interior valley, either of five lesser ones, and of four ridges separating them, or else a deep central valley of denudation, bordered on each side by a *double* terrace; or, in other words, a valley of three platforms of level in place of two between the high exterior crests. An intermediate structure, derived from an erosion developing six sets of alternating hard and soft strata, is likewise of frequent occurrence. This is where the lower or first formation is a hard one, and has been denuded but not cut through by the water, and projects therefore as a simple or single-crested monoclinal ridge in the middle of the central valley, which, when it is prominent, it even divides into two monoclinal ones. This more extreme degree of exposure of the central arch is conspicuous in the Jura, especially in the chain of Mont-Terrible, and is the type of Thurman's upheavals of the *Fourth Order*. It there constitutes the limit to which the elevation and denudation of the anticlinals have proceeded. The most developed anticlinals of the Appalachians are likewise not advanced beyond this point of orographic structure, nor do they indeed present it in quite its fullest completeness. Only the widely and deeply-denuded anticlinal belts of Nittany Valley and Morrison's Cove display it in any very distinct degree, and there even it is not the prominent feature. It exists in those belts where the erosion has extended down to the relatively harder Auroral magnesian limestone, and especially where the base of this formation, the Auroral sandstone, has been reached and exposed. In this latter case there is an anticlinal sandstone ridge in the middle of the valley; and generally, in fact, the whole bed of the valley is more or less arched through the superior hardness of the whole Auroral series over that of the Matinal soft limestone and slate, outcropping along each margin of the plain. In a fainter degree, therefore, even the other narrower limestone valleys of the same part of the chain, which expose no medial ridge of the Auroral sandstone, are instances of an incipient advance towards the structure we are now considering, of an anticlinal of six alternating hard and soft strata, cut down by water to the exposing of the lowest in an unbroken arch. As this feature of the greater anticlinals of Pennsylvania is connected with important economic interests, no less than with these laws of orographic structure, I will here present a section of this type of denudation. It will stand for a profile of Nittany Valley, and the enclosing mountains in a meridian E. of Bellefont.—(Fig. 742.)

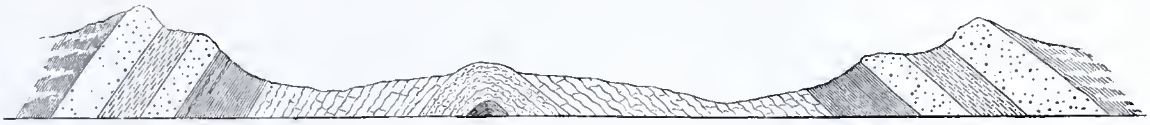


Fig. 742.—Complex Valley of Elevation, with central Anticlinal Ridge.

The exposure of the lower Auroral rocks, especially of the sandstone ridge, is invariably attended by two conditions interesting to the inhabitants—great nest-deposits of hæmatitic iron-ore, and barrenness as to water.

The above four or five varieties of our anticlinal mountains, constitute in reality but one series of the successive stages of elevation and erosion of the larger anticlinal waves. They owe their features primarily to the fact of an alternation in the relative hardness and softness of the strata uplifted and cut into, and each derives its special character merely from the particular amount of the vertical elevation at the arch, and the extent of the denudation, or the stage, at which the washing off or excavation paused. Of course, the depth to which this erosion would penetrate, with a given energy and duration in the removing waters, would be somewhat influenced by conditions independent of the simple height of the exposed anticlinal wave; such, for example, as the relative thicknesses of the hard and soft alternating strata, also their differences of hardness and of softness, and especially the greater or less extent to which the outer strata might be cracked, dislocated, and made to yawn on the back of the anticlinal by the undulating uplifting crust-movement preceding or accompanying the lashing of the waters. These several phases of erosion of the Appalachian anticlinals are to be seen both detached and blended together, in the district of the Juniata River, where the four forms above described are beautifully typed in the Tuscarora, the Blue Ridge, the Shade, and the Blacklog mountains; and blended together, or graduating into each other, in the mountain-group of Union, Centre, and Mifflin counties, where each of the single anticlinal crests of Union, ascending W., divides into two monoclinal ridges, with a high plateau between to form the second phase of a simple high valley of denudation; and out of the middle of this again, at its W. end, there rises by-and-by a central unbroken anticlinal ridge or knob, to make, with the two outer crests, and the now double plateau, the third or triple-crested form; while still farther forward, in Centre County, with the progressive rising of the axis, and deepening of the trench upon it, the fourth marked type is developed in the beautiful elliptical coves or oval-headed valleys, which scooped deep in the Matinal slates and limestones, are bounded first by two inner monoclinal crests or shoulders forking from the central knob, and externally by the two crests before produced by the similar forking of the original single ridge, the high terraced branches of the upper valley or plateau being embraced between these inner and outer crests.

The attentive student of our Appalachian geology will readily perceive that a still further amount of uplift or flexure in the anticlinals of Centre County would have brought the hard Primal sandstones which underlie the soft limestone of the valleys, and even the soft slates beneath those sandstones, equally within the trenching force of the waters, andthat in this case there would have been produced a fifth and a sixth distinct type; one, the first of these, with a high central ridge in the valley, and the other with this ridge forking into two escarpments, and enclosing a deep interior valley, relatively lower by several hundred feet than the beds of the present ones. Such more complex anticlinal valleys of erosion, resulting from denudation upon six or seven in place of five alternately hard and soft strata, do exist, as we have seen, in the Jura Mountains, and even in a faint degree in the valleys of Centre County. In the Jura, from the extreme relative softness of the more easily excavated beds, and the firm, cliff-forming, jointed character of the limestones, which are the harder members, the scenery of some of these deep secluded and wall-surrounded oval valleys is wonderfully impressive and picturesque.

Though the Swiss geologists, especially Thurman and Gressly, have classified the denuded anticlinal valleys of the Jura chain somewhat as I have now been grouping those of the Appalachians, their arrangement, it will be seen, is not complete, there being really five phases of structure covered by Thurman's four orders of upheaval. Gressly has ascribed to these anticlinals, moreover, an erroneous origin. He assumes them to have resulted from a subterranean explosive volcanic action, exerted at certain points in foci along the anticlinals, and imputes too little agency to the carving force of waters working through breaches in the ridges, and scooping them at such enfeebled points into these terraced oval valleys by the revolving eddying currents of the tremendous waves which swept transversely all the summits of this chain. To this excavating action of water, propelled in gigantic billows and rushing sheets across our anticlinal ridges, when these were lifted by successive but sudden earthquake movements, higher and higher through and above the ocean, while at each paroxysm they were becoming more and more permanently arched, we must, I think, attribute, conjointly with the differences in the susceptibility of the strata to erosion, all the phenomena of excavation which I have described.

IV.—FEATURES OF EROSION IN SYNCLINAL BELTS.

a. *Where the highest Strata exposed, or those of the Synclinal Axis or Trough of the Wave, are the hardest—of this Class there are several Varieties.*

1. *Simple Synclinal Ridges.*—These occur where the highest strata, or those in the middle or axis of the flexure, are the *hardest.* Where such upper harder rocks are of one nearly uniform degree of resisting strength, they form smooth slopes, whose steepness is progressively greater as we ascend to the edge or very brow of the plateau which, narrower or wider, invariably terminates all ridges thus composed having synclinal dips. But where the upper firmer rocks are alternating in degree of hardness, the sides are benched or terraced, but the shelves for the most part are less sloping, and more ravined than on the faces of anticlinal ridges. The narrowness or width of the summits of these synclinal ridges, depends mainly on the steeper or gentler degree of dip of the strata at the axis, or the closer or more open form of the flexure. Where the synclinal dips are very steep, or the fold much compressed, the ridge is usually a narrow, flat-topped crest, or is cut by cross denudation into a chain of oval ridges or flattish hills or knobs. Such are the features in which many of our more slender synclinal sandstone ridges terminate. Again, where the dips are flatter, and the synclinal curve gentler and more open, the summit is broader, and is usually a true table-land or high plateau, being sometimes even basin-shaped. (See Figs. 736 and 737.)

Examples.—The longer simpler spurs of the Broad Mountain, Schuylkill County, and those of the Lehigh coal-basins, have this structure; also the terminating spurs of Nittany and other synclinal mountains of the Levant lower sandstones.

2. *Triple Synclinal Ridges, or a Central Synclinal Ridge or Plateau enclosed by two Monoclinal Ridges or Shoulders).*—This second feature of synclinal topography is where the synclinal wave admits within it three several strata or series of rocks above those of the exterior country, or four in all—namely, a hard, a relatively soft, and again a hard group. In this instance we will have the first or lowest hard mass basining or sinking from a high plateau, and forking into two crests or ridges, and admitting a double narrow valley within it, and between these two valleys of softer matter will rise in a ridge or plateau the uppermost hard formation, placed centrally like a citadel enclosed by its moat and exterior rampart.

We have an example of this structure in the Broad-Top Mountain of the Juniata, where the hard Vespertine rocks of the Terrace Mountain and Sideling Hill enclose the forking valley of Trough Creek, with its soft Umbral shales; and this embraces between its branches the table-land of the Broad-Top Mountain, composed of the harder inferior strata of the semi-bituminous Coal-measures. It is likewise beautifully exhibited in the ridges which divide the branches of Kishacoquillas Valley and those of Penn's Valley, and indeed in many others of our synclinal Levant mountains, where the lower Levant sandstone forms a first plateau, and the upper a higher ridge resting upon it.

b. *Where the highest Strata embraced in the Synclinal flexure are relatively soft—of this Class likewise there are several Varieties.*

1. *Simple Synclinal Valleys and basin-shaped Plateaus* (synclinals where the highest strata are *softer* than those supporting them).—Such belts are invariably trough or basin shaped. Of this type are the coal-basins of the anthracite region of Pennsylvania, if viewed from their exterior red-shale valleys. There the relatively hard conglomerates, at the base of the Coal-measures, rising in steep narrow monoclinal ridges on each side, basin under these softer upper coal-strata reposing nearer the synclinal axis, and the harder less erosible rock *is also underlaid* by easily-denuded strata. In these instances the harder rocks either form *plateaus* basining in their centres, but lifted above the exterior plain or valleys of the lower softer group; or else two parallel ridges, with the upper softer strata between them, and the lower softer series in a belt on the outside of each. Both of these conditions occur in the great synclinal basins of the Pennsylvania anthracite, where the soft Umbral red shale surrounds in some cases, as in the Lehigh district, high table-land basins of the Coal-measures; and in other cases encircles in narrow exterior valleys the steep narrow ridges of the harder strata which enclose the often equally depressed interior valley-basins that hold the Coal-measures.

Examples.—The tongue-shaped valleys or basins of Umbral red shale, enclosed by ridges of Vespertine hard sandstones, like the Lehigh Kettle, Hunter's Cove, and Parnell's Mountain, in Franklin County, are good examples.

2. *Complex Synclinal Valleys, or concentric Valleys of Depression.*—This type of ridges and valleys is presented where there are four alternating hard and soft groups of strata above that of the general plain of the country, or five in all, and the uppermost a soft group. In this, as in the previous case, the highest soft strata lie in a topographical

basin, between monoclinal inward-dipping ridges of the next inferior hard rocks, which unite at the head of the basin in a high synclinal knob ; and this inner basin itself rests within another, scooped in the lowest soft group which, in its turn, is similarly enclosed by two converging ridges of the lowest of the hard masses, or the first of the four formations. Such concentric synclinal troughs bear a striking resemblance to a nest of spoons, where a smaller spoon rests within a larger one.

The form here illustrated is that derived from five groups of alternately hard and soft strata, but there are synclinal belts or basins in our Appalachian chain, where the erosion of seven or even of nine such masses at their outcrops has produced a symmetrical and curious topography, consisting of three or four concentric basins, each basin being composed of a soft easily-excavated member resting within an enclosing mountain-rim of hard resisting sandstones, and each, save the innermost or uppermost of the softer strata, branching into two narrow parallel valleys from a regular terminating spoon-shaped cove. While these narrow lateral valleys thus unite in pairs in the terminating synclinal coves, the ridges which separate the valleys converge by the same law, and coalesce by pairs at the ends of the basins in high synclinal plateaus and swelling mountain-knobs—usually the loftiest eminences of the symmetrically undulated portions of the Appalachian chain.

Very similar are the topographical features of the synclinal mountain-tracts of the Jura and other chains, where the same essential conditions of structure and stratification prevail, the anticlinal and synclinal flexures approximately parallel, and the region consisting of strata alternately soft and resisting to the action of the waters which eroded their outcrops. Indeed, it is impossible to imagine how, with identical combinations of the physical circumstances, there should not have been produced an identical topographical structure, and a close resemblance in all the phases of scenery which result from the forms of the ridges, hills, and valleys. Through the agency of the same few simple controlling conditions of undulation in the crust, and of composition in its materials, arises that wonderful and impressive likeness in scenery and aspect which so frequently exists between distantly remote tracts of the earth's surface—not merely narrow local spots, but whole mountain-zones. Hence it is that an American, familiar with the Appalachian ridges and deep trough-like valleys, and the wild gorges and defiles which connect these, is impressed, on traversing the Jura chain, everywhere with a something in its yet more picturesque passes and perspectives which, with the freshness of another land in the mere outward accessories of sky and verdure, and the garb of a peculiar life, has yet the deeper charm of a profound and pervading likeness to the scenery of his home in all its bolder features. These two mountain systems are creations upon one and the same essential plan, modelled both upon one archetype idea, through the secondary agency of one class and combination of forces. The same gigantic billowy undulations have ridged the crust in both regions, and similar stupendous currents of repeatedly-uplifted waters have cut down the crests of the great crust-waves in exactly the same manner, ploughed lengthwise the softer strata into similar groups of narrow valleys, and breached crosswise the newly-made ridges into the same deep notches and winding cliff-confined gaps and rocky passes. No marvel, then, that Nature should wear the same face to her beholder in lands so similarly created ; for her features, in all such instances, in their strongest and their softest and most subtle lines, are but the external expressions of the same class of forces or pressures with which her great pulse has throbbed in her moods of highest energy or of gentlest life. The tone of the landscape is the same, however unlike its outward incidentals, and it is the same by reason of the identity in the movements and actions which the now sleeping upheaved strata indicate or express.

Returning from this digression to descriptive topics connected with features of structure in the undulated and eroded region of the Appalachians, and of other similarly-formed mountain-chains, I may remark, as a generalisation upon the details thus far submitted, that all the conditions of orographic* structure here illustrated, all the physiognomy of the surface produced by the denudation of anticlinals and synclinals composed of alternating hard and soft strata, and by that of their combinations which give rise to the beautiful reflexed or zigzag windings of certain mountain-crests and their included valleys, and to the meandering outcrops which so perplex and disappoint the miners of our Appalachian anthracite coal-seams, and, in fine, all the possible modes in which the strata are presented at the surface, are referable to simple geometrical laws, and are deducible from the few conditions of the intersection of the approximately level, yet everywhere unevenly acting and locally-irregular knife edge of the cutting waters, with the unequally exposed strata in the variously-presented anticlinal and synclinal waves of the crust.

In the forms of those solid crust-undulations, their symmetrical and unsymmetrical arching and troughing, in their various dislocations, in their parallelism, and in their want of it, their rising and expanding singly and in groups, and their sinking, contracting, and expiring, and in their modes of coalescing and of fading out one into another, reside the conditions under which the strata they contain have been exposed to or protected from the great *planing* mechanism of the horizontally-working waters.

But the horizontally-moving waters have by no means acted on the corrugated and dislocated surfaces over which they have so often rushed in broad diffused sheets, or in contracted and grooving currents, with an absolute horizontality. The waved and ridged floor which they washed, at times transiently, at times with a somewhat prolonged presence, must, even if we can assume it to have been itself in repose, which the very hypothesis of the upheaval of the crust-undulations prohibits, have deflected the waters into many local eddies and internal streams, variously oblique to the general plane of their motion, as up the slopes of the newly-born mountain-waves, through the freshly-opened breaches in their cracking summits, and down their opposite flanks with an accelerating speed, that has ploughed them everywhere with ravines, or gashed them with deep and yawning gulfs. Thus, while the internal crust-motions exposed the strata unequally to the erosive power of the displaced waters, the waters in their turn, worked unequally on the strata upturned to meet their fury, and therefore *all* the resulting conditions of the two combined agencies concurring to beautiful and harmonious results, while so apparently antagonistic, are only to be understood when we can consider and analyse the direct and reflected operations of both the influence of the moving inundation, to cut down and modify in shape the barriers lifted to oppose it, and the influence of the thus newly-created local features to modify and divert the localised currents of the retreating sea, for the production of those last-impressed finer and gentler features with which the waters, working with more than a sculptor's power and delicacy of touch, have shaped the face of the lands they have chiselled, softened, and adorned.

---

* *Orographic*, appertaining to mountain-chains.

The annexed sections represent the general structure of the *simple synclinal ridges* and spurs, the first (Fig. 743) where the fold is compressed, as in Egg Hill, in Centre County, and the second (Fig. 744) where it is more open, as in the W. part of the Nittany Mountain. The anthracite coal-basins end in spurs of both of these forms dependent on the closeness of the flexure.

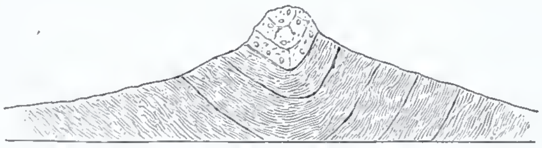


Fig. 743.—Simple Synclinal Ridge, flexure close.

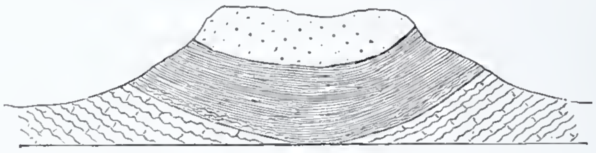


Fig. 744.—Simple Synclinal Ridge, flexure open.

The sections (Figs. 745 and 746) here attached display two very usual forms of the *triple synclinal ridges ;* the first being that of a synclinal ridge or knob enclosed between two monoclinal ridges, the very usual structure of the belts enclosing the terminal spurs of the anthracite basins ; the second, the prevailing condition in the synclinal Levant ridges in their fullest development as they occur S.W. of the Susquehanna, but visible on a lesser scale in various other formations.

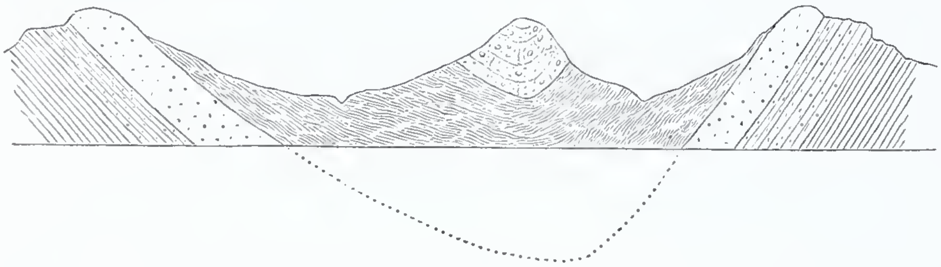


Fig. 745.—Synclinal Ridge in Synclinal Valley, or Triple Synclinal Ridge.

Perhaps the most common form of the *simple synclinal basins* is that which is here annexed (Fig. 747.) It will represent such slender trough-shaped ridges as Parnell's, where the Levant series presents, as it does in its extreme S.E. outcrop, but one crest-forming sandstone ; or it gives us the general structure very fairly of the more slender and tapering anthracite coal-basins, such as the Dauphin, Wiconisco, and Shamokin basins in their W. parts, if we overlook the absence of the lesser benches marking the outcrops of the coal-beds. Of course, these synclinals are of various features, the dip and hardness of the strata modifying these greatly.

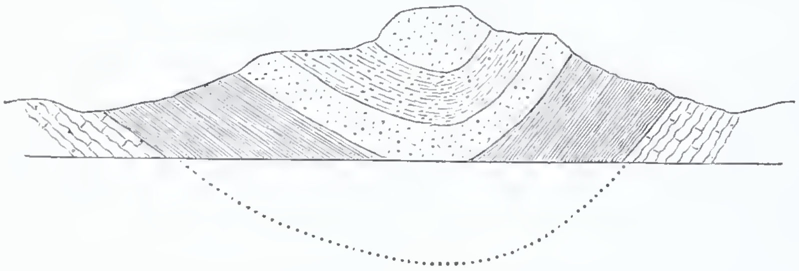


Fig. 746.—Triple Synclinal Ridge or Terrace.

A very usual form of the *complex synclinal valleys* is shown in the accompanying cut (Fig. 749). This topography is characteristic of the belts which contain the anthracite Coal-measures, viewing the basins from the valleys or plains external to their outside ridges. The double mountain-barrier due to the superior hardness of the Vespertine conglomerate and sandstone and Seral conglomerate at the base of the Coal-measures, and relative feeble cohesion of the Umbral red shale between them, is an interesting feature not common in other coal-formations. Of course, the lesser geological and terraced features of structure and composition—namely, undulations of the softer coal-beds—are all omitted.

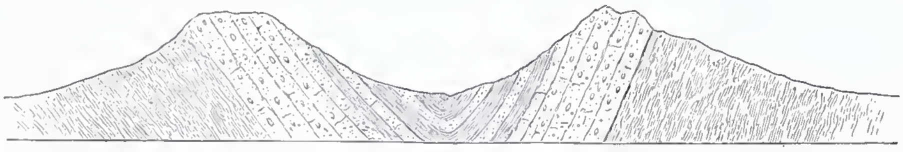


Fig. 747.—Simple Synclinal Valley or Basin.

A modification of this structure (Fig. 748) distinguishes all the synclinal basins of the Levant sandstones of the counties S.W. of the Susquehanna, where these synclinals are wide and deep enough to receive in the middle of the trough a portion of the lower soft slates of the Surgent series. As in the case of the two forms of our triple synclinal ridges, we have, in the comparison of the two varieties of this more complex type of our synclinals, essential differences, dependent on

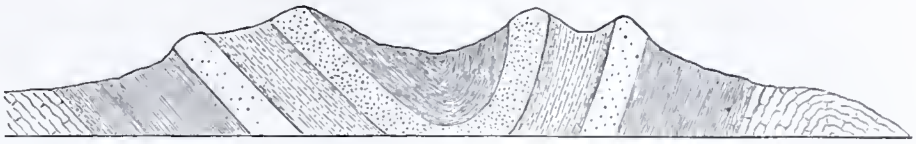


FIG. 748.—Complex Synclinal Mountain.

the relations of hardness of the two sets of strata involved in them. Indeed, all the synclinals, simple and complex ridges, and simple and complex basins or valleys, have, where the materials of the ridges are the Levant sandstones, very different orographic features from those which the same types exhibit where the mountain-rocks are the carboniferous conglomerates. And the main reason of this contrast is the very marked dissimilarity in thickness and relative softness of the interposed less cohering argillaceous stratum in each case. In the Levant series, the middle red sandstone, though softer than the over and under lying silicious grey sandstones, is yet of too firm a texture to be deeply eroded; and from this cause, and its being only a few hundred feet in thickness, it forms high monoclinal shoulders, and not deep monoclinal valleys like those in the softer and far thicker carboniferous red shales of the coal-basins.

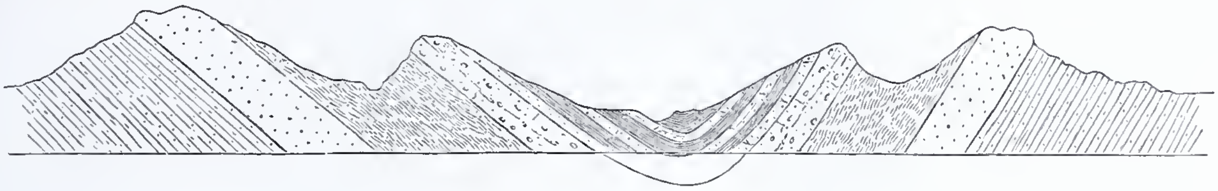


FIG. 749.—Complex Synclinal Valley.

FEATURES OF LOCAL EROSION.

Having now treated of the various general phases of mountain structure arising from the erosion of monoclinal, anticlinal, and synclinal belts of alternately resisting and yielding strata, without regard to any features but those due to the action of diffused horizontally-moving waters, it is needful to consider, in the next place, those lesser and more local modifications of these broader elements of the scenery which have resulted from the reaction upon the waters by particular forms of the surface previously established, such as deflecting barriers, steep mountain-slopes, high terraces pouring off the floods, and deep transverse gorges dividing the broad flowing sheets into special and more sharply-trenching currents, which have worked in unusual directions, and at levels oftentimes different from those of the larger-moving tide, which in its earlier stages shaped the mountain-summits and their higher valleys. These minor aspects of erosion, insignificant though they are for the most part in the crests, and on the flanks of the ridges in the general scale of the landscape, are, however, of prominent interest to the geological observer, and of the highest local importance to the mining engineer and the practical explorer of the outcrops of the denuded strata.

They include nearly all the cases of local deflections of outcrops from their more prevailing or normal directions, as produced by horizontal denudation; and therefore it is proper in this, which is intended as both a scientific and a practical chapter on the external physical structure of the Appalachian chain, to elucidate the various modes in which the lines of the strata at the surface are caused to curve, elbow, and wind, and to ascend and descend the hill-slopes in obedience to simple general geometric laws of the intersection of surfaces.

These features of local erosion may be grouped under the following forms :—

Local Erosion of Horizontal Strata.	Local Erosion of Anticlinal Strata.
„ „ of Monoclinal Strata.	„ „ of Synclinal Strata.

V.—LOCAL EROSION OF HORIZONTAL STRATA.

a. *Where the Strata have the same general degree of Hardness.*

1. *Confluent Ravines intersecting a level Plain.*—This feature, the result of a diffused erosion of a nearly horizontal plain or plateau, is variously modified by special conditions in the floor which the waters washed, and by the manner of movement of the fluid,—influences to be considered in a future page. But the essential character in every case is that of a confluence of narrow and shallow channels of drainage to constitute larger ones, and the union of these again to form others still wider and deeper. As the channels or valleys deepen in the direction of the currents which passed through them, we find that their borders are more and more intersected by short lateral and relatively steep ravines, and that each large valley receives other streams of compound drainage like itself, longer and larger, as this is farther from its own sources. The whole is like a flattened plant, built up of continually subdividing branches; and as in the instance of the plant, each tribe exhibits a different species of symmetry in its plan of ramification, each eroded district has its own law of convergence of its channels, and its distinctive resulting topography dependent on a delicate yet positive equilibrium in every case between the excavating fluid and its resisting bed. This ramified erosion is of course most symmetrical where the surface is almost absolutely level, and the strata are very homogeneous; but as

these conditions rarely prevail over great areas, it is chiefly on the small scale that we meet with it in its highest degrees of regularity. No tract of Pennsylvania has the structure essential to it on an extended scale, for nowhere are both the general surface and the stratification sufficiently horizontal to have allowed the denuding waters to produce it. No mere section of a surface thus eroded can convey a true conception of its complicated features; but in the next chapter, where allusion will be made to the modes of origin of the various types of scenery, a sketch of this variety will be presented.

2. *Rounded conical Hills, and insulated Saucer-shaped Hollows.*—This structure of the surface occurs in its fullest perfection where the general surface of the country is level, and the superficial deposit in which these features reside is imperfectly stratified, or composed of very incoherent materials, as is the case with the great *drift*-deposit which covers all the Northern temperate and arctic latitudes of both the Asiatic-European, and North American continents. I do not know that this type of surface is indeed anywhere to be met with exterior to the limits of the drift-formation, of the mode of origin of which it is eminently expressive. It seems to have resulted from an excessive turbulence in the waters which transported the drift, and to be connected more immediately with whirling and eddying currents. These have scooped the stratum of loose fragmentary material which the general sheet of moving water strewed along its floor into the dish-like depressions which are so common, and have in other places piled the pebbly mass into the conical mounds so characteristic of it. Elsewhere, again, the currents have left mounds of various shapes outstanding from the plain they belong to, by their gyratory and deflected erosion. In proof of this view of the origin of the features described, we invariably find them most to abound in the seaboard belts of the drift where the general continental inundation, after just depositing the drift below the then existing sea-level, was thrown into the wildest eddyings by surging to and fro above it. Hence the prevalence of the phenomena on the S. coasts of Long Island and of Massachusetts. The same feature of conical hills and hollows is met with very abundantly in the plains among the mountains of New England under precisely those conditions of the topography which admit of the same explanation, that of conflicting waters thrown into strong whirling and eddying currents.

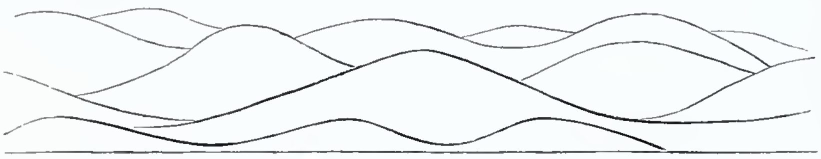


Fig. 750.—Mounds and Hollows in the Drift.

It is only in Northern Pennsylvania that the drift stratum exists at all within the State, and even there it is so near its extreme S. margin, and is consequently so thinly spread over the upland tracts, that the features referred to are by no means as marked as they are in New England and New York. Wherever the deposit possesses an ample thickness, as in the river-valleys and the plains enclosed by the S. barriers which arrested the drift, it exhibits these phenomena; but the features which especially characterise it are the so-called *river terraces*, a description of which has been already given.

b. *Where the Strata alternate in Hardness.*

Of course, the contours impressed on any tract of the surface by the erosion of an approximately horizontal set of strata of various degrees of hardness and softness, will vary with every variation in these relationships of firmness in the rocks. Where the contrasts are great in this respect, the convex contours or projecting outcrops of the harder beds will be prominent and steep, and the concave slopes of the softer masses very gentle and retreating; where, on the other hand, these differences in cohesiveness are small, the convex and concave lines of the ground are much less distinct. An extreme disparity in the texture of the beds produces an alternation of precipitous escarpments and horizontal terraces, whereas a trivial inequality shows itself in no more than a slightly-undulated continuous slope.

1. *Terraced Hills, or Camp-like Eminences on Surfaces of the Plateaus and Plains.*—This feature occurs perhaps most conspicuously in the bituminous coal-fields, where the coal-beds and their attendant shales and marls are very soft, and in strong contrast, as respects erosibility, with the harder sandstones and grits. Where the terraces or gentle slopes are easily traceable through a district, they constitute a very admirable guide to the outcrops of the various coal-beds and layers of soft fire-clays; in fact, in a country which has its geology thus defined in its topography—and this is the case with all the United States coal-fields not buried under drift—the position and range of all the members of the formation may be learned and recorded by the geological explorer, if aided by minute and accurate maps, and by sufficient time, with the greatest facility.

If the strata are almost perfectly horizontal, the benches on the hills curve in and out with each recess and projection, precisely like so many water-lines at different levels, as if the sea had subsided successively from one station of erosion to another. They will follow pretty accurately the contour-lines of a map of the district. Where the hills are insulated, and either conical or irregular in shape, these terraces pass entirely round their upper insulated portions.

If the strata, on the other hand, are not absolutely horizontal, the benches marking the margins of the coals and other soft layers will enclose the upper parts of the hills, not symmetrically, but somewhat obliquely. Where there is more than a trivial inclination, we have the conditions of local erosion of monoclinal belts, to be considered in another section.

The annexed cut shows a body of nearly horizontal coal strata thus benched in the slopes and hills.—(Fig. 751.)

2. *Terraced Ravines and confluent Valleys.*—Where a plain or plateau composed of alternately harder and softer strata is cut off by terminating escarpments, or intersected by long and deep valleys, these escarpments, and the borders of these valleys, are trenched by steep ravines, or by steep branching or confluent shorter valleys, which are more or less terraced. If the strata are quite level, these terraces maintain the same levels on the opposite sides of the ravines, otherwise they change their heights on the hill-sides just in proportion to the space of the ravines and the degree of inclination in the strata. A careful measurement of their elements, and a little calculation, will enable the explorer at all times to discover the position of any stratum across a ravine or valley, and he will usually be much assisted in the identification, by recognising in their new positions the corresponding slopes and benches of the previously familiar beds. It is thus that he traces the coal-seams from hill to hill across the ravines and wider river-valleys which they skip.—(Fig. 752.)

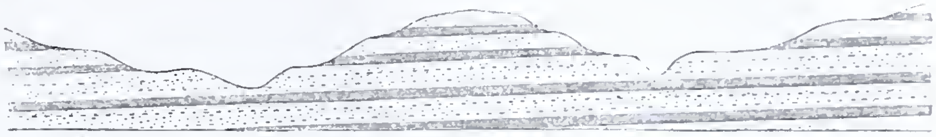


Fig. 751.—Benched Outcrop of Coal Strata.

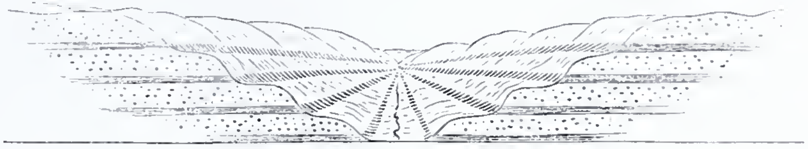


Fig. 752.—Terraced Hill-sides.

VI.—LOCAL EROSION OF MONOCLINAL STRATA.

a. *Transverse Ravines.*

These are of various forms, and variously deflect the outcrops of the strata obediently to their forms, and to the parts of the monoclinal belts which they intersect. They may cross the strata either perpendicularly or obliquely, and they may be either level ravines or sloping ones; and again, they may slope *with* the dip, or *against* it. Furthermore, the strata intersected may outcrop to form a plain, a ridge, or a valley. The more important varieties of these transverse trenches seem to be the following:—

1. *Level Ravines perpendicular to the Strike.*—The ravines or trenches of this class are apt to have the slopes of their two sides alike, and when this is the case, they cause precisely the same amount of deflection in the outcrops of the dipping strata. This deflection, of course, is greatest, or it amounts to a right angle in the dipward direction when the borders of the ravine are perpendicular; or, in other words, when it is a precipitous gorge. And it is less and less just in proportion as the slopes are more and more gentle. By deflection is here meant the angular change of direction from the *horizontal* line of outcrop of a stratum. The rapidity, then, with which *oblique* lines of outcrop will descend along the sloping side of a ravine or valley will depend on these two elements—the inclination of the stratum itself, and the inclination of the hill-side which intersects it; and the angle of descent along this hill-side can be readily calculated for every case by the methods of descriptive geometry which define the laws of the intersections of planes.

To render this effect of deflection of the line of horizontal outcrop clearer by an example, let us imagine a stratum—a bed of coal, if we choose—to dip, say to the S., at an angle of 45°; and let us suppose that the ravine crossing it, and running N. and S., has its E. bank sloping W., also at 45° to the horizon; then the line of intersection of these two planes, or that which marks the deflected course of the outcrop descending to the bed of the valley, will dip exactly towards the S.W. If, again, the sloping side of the valley be not of one constant declivity, but a curvilinear surface, then the line of outcrop will itself become a curve by the intersection of this curved surface with the plane one of the stratum. But further still, it frequently arises in nature that both the dip plane of the stratum and the sloping side of the ravine are curving planes, either both concave surfaces or both convex, or the stratum convex and the surface concave; or, fourthly, the surface convex, and the stratum concave. From all of which it will be seen that the actual lines of sloping outcrop in these, the simplest of ravines, being the intersections of such variously-related surfaces, are by no means easily traced, or even theoretically calculated. The best practical sagacity of the mining engineer and geologist is constantly put in requisition to trace the outcrops of the coal-seams, and other strata of our anthracite basins, turned from their normal courses into the most subtle curves by this intersection of curving planes of erosion with curving planes of dip.

I here append (Fig. 753) a simple topographical sketch—a bird's-eye view—of this variety of ravine, showing the deflections it produces.

2. *Level Ravines oblique to the Strike.*—In these ravines and valleys the two opposite sides have seldom the same inclination to the horizon; and the reason for this is obvious. In those which intersect the strata at right angles, the waters have pressed with nearly equal force on both borders of the excavated trench; but in those which cut the beds obliquely, the erosive impulse has been strongest on that side towards which

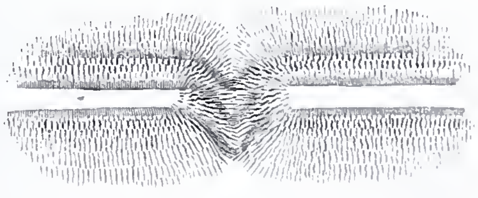


Fig. 753.—Level Ravine in Monoclinal Ridge viewed from above, perpendicular to Strike.

the ravine has been deflected, leading to more under-cutting, and therefore to a greater steepness than on the opposite border. Of course, the amount of deflection of the strata from their lines of horizontal outcrop is greatest on that side of the ravine which adjoins the acute angle formed between the general course of the ravine in the dipward direction and the line of strike; and from two causes—the acuteness of this angle, and the superior steepness of this side of the valley.

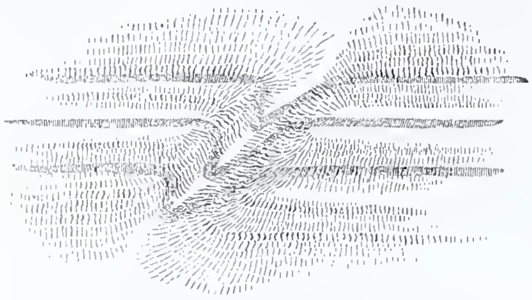


Fig. 754.—Level Ravine in Monoclinal Ridge, oblique to Strike.

A simple topographical sketch (Fig. 754) will sufficiently explain this obvious feature, which the unpractised explorer of strata may, nevertheless, easily overlook.

3. *Sloping Ravines descending in the Direction of the Dip.*—These are either perpendicular in direction to the strike, or more or less oblique—that is to say, they either coincide with the line of dip, or with some line between this and that of the strike. Those which intersect the sides of monoclinal ridges are very generally perpendicular to the strike; this being the natural course of the waters breaking over the crests of such ridges, and dashing down their flanks. It will suffice to consider this class.

These ravines on the dipward or face side of monoclinal belts are of two varieties—very different in their effects in deflecting the outcrops of the strata which they cut—according as they have a steeper or a gentler inclination than the strata themselves.

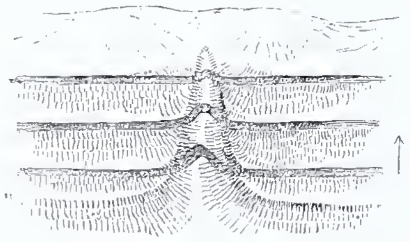


Fig. 755.—Sloping Ravine, descending in the direction of the dip more rapidly than the strata do, towards the observer.

1*st Variety.*—Where the ravines descend more *rapidly* in the direction of the dip than the strata do.

In monoclinal belts cut by such ravines there are necessarily two outcrops, a lower and an upper, of the strata intersected, and the *lower* outcrops are deflected *up-hill*—the steepness of the sides of the ravine and the degree of inclination of the rocks controlling the extent or degree of the deflection. In such deflections along the sides of the ravine, the edges of the beds converge as they ascend the ravine and unite in succession at different heights in its sloping bed to form V-shaped outcrops, the points of the V being directed upwards. This effect of sloping ravines on sloping strata has been neatly illustrated by Sopwith in his models of some of the simpler conditions of the denudation of imbedded rocks.

Instances of it are very numerous on both a large and a small scale in the deeply-channelled districts of our Western bituminous coal-fields, where the rocks have a low degree of dip.

The feature is here indicated in a topographical sketch (Fig. 755.)

2*d Variety.*—Where the ravines descend more *gently* in the direction of the dip than the strata do. This condition of things is connected with but one outcrop to each stratum—a natural consequence of the greater steepness of the dip over that of the intersecting valleys. The ravines not cutting through the upper beds as in the other case, but only trenching their higher outcropping margins, these edges are deflected in this instance *down-hill*, precisely in the manner in which they are along the sides of level ravines intersecting similar monoclinal belts. The V's therefore point with the dip. The degree of the deflection of the horizontal outcrop of each stratum will depend on the steepness of the sides of the trench, and its more or less trumpet-like expansion; and the extent of the deflection, or the length of the V to its point at its water-level in the bed of the ravine, will mainly depend on the less or greater difference between the slope of the ravine and the dip of the stratum; the less this difference, the more tapering and longer, of course, the convergence of the two edges of each intersected bed.

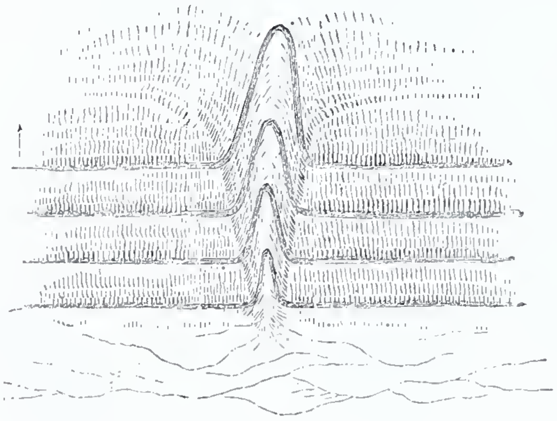


Fig. 756.—Sloping Ravine descending in the direction of the dip, more gently than the Strata do, towards the observer.

A sketch of this very common variety of ravine with its outcrops is here given (Fig. 756.) It is the form characteristic of the ridges and hill-sides of all the anthracite basins where the angle of dip is considerable.

3. *Sloping Ravines cutting Terraces on the dipward side of a Ridge.*—Wherever a ravine or trench descending a ridge on either its dipward or cropward side, crosses longitudinal terraces, these terraces are eroded more or less in their longitudinal direction, and are deflected downward into the ravine; and so likewise are the outcrops of the harder strata which divide the terraces or support them. Each such ravine is therefore composed of a main stem and lateral curving branches, and may in many cases be likened to a great expanded plant lying on the slope of the hill. Upon the relative breadth of the terraces denuded, and on other elements, such as the dip, will depend the magnitude, and indeed the shape, of these side-ravines, swinging in graceful sweeps from the benches in which they originate, down into the beds of the main transverse trenches. Where the mountain-side chances to include strata

of very unequal hardness in few alternations, and the soft ones are thick, and susceptible of deep erosion, and the whole erosion is on a great scale, the ravines being sharp and profound, these lateral enlargements at each terrace become great oval valleys. Usually the ravine originates or has its head in a terrace in one of these dish-like slanting excavations in the flank of the ridge. The sloping, shallow, oval valley gathering the drainage from a wide circumference on the mountain platform, pours it inward and forward, and finally through a contraction of the ravine, or, it may be, a mere narrow notch in the hard formation which forms the lower front edge of the terrace. Such are the *cirques* of the Alps, the great feeders of the upper glaciers. A topographical sketch (Fig. 757) is here annexed of this character of mountain ravine or valley.

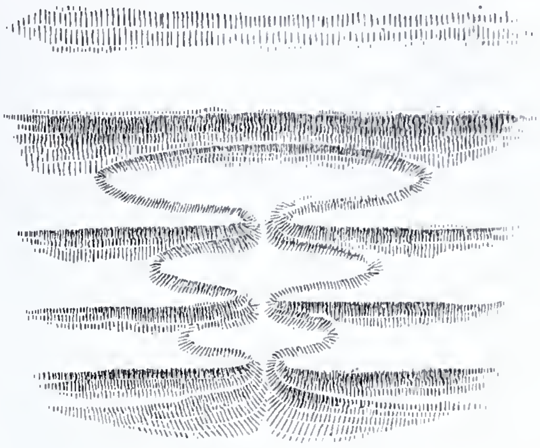


FIG. 757.—Sloping Ravines cutting Terraces on the dipward side of a Ridge.

4. *Sloping Ravines descending against the Dip*, or on the back or outcrop sides of monoclinal ridges :—

1*st Variety : descending Ridges but little terraced.*—Ravines in this position, widening, of course, as they descend, in a direction opposite to that of the dip of the strata trenched, deflect their outcropping edges in V-shaped descending lines in the direction of the dip, or from the mouth of the ravine. The lowest strata exposed endwise in the sides of such a ravine are those nearest its mouth, while the lowest thus accessible from the bed of a trench on the *face side* of a monoclinal ridge, where the dip exceeds the angle of descent of the channel, are those farthest in from the mouth.

The ravines of the class now considered are extremely numerous on the external sides of the monoclinal mountain ridges which enclose the anthracite coal-basins of Pennsylvania, and indeed belong, as an invariable feature, to all our monoclinal ridges composed of a hard crest-rock, and of some softer underlying formation.

2*d Variety : descending from Terraces on the Outcrop Side of a Ridge or Plateau.*—This is an interesting species of the ravine descending the cropward side of a raised monoclinal belt of strata. If the terrace which it crosses is wider, and supported by a very hard resisting stratum, we are sure to find the terrace itself denuded longitudinally on each side of the ravine in a long descending tributary trench or valley. Where only one such wide terrace occurs on the side of the ridge, the ravine usually has its source or head in a wide oval expansion, embracing these side-ravines as wings. These are common on the cropward slopes of the ridges of the Levant sandstones, the ravines breaching the lower or Levant grey sandstone, and commencing in the terraces of the softer Levant red sandstone above it. They present themselves on a grand scale in the Alps, where they terminate upward in one variety of the cirques or oval dish-like hollows high on the slopes of those mountains at the sources of their glaciers. Other cirques, it has been shown, are similar expansions of the upper parts of the class of ravines belonging to the dipward flanks of those mountains.

A topographical diagram (Fig. 758) is here offered of the usual form of the ravines of this species in our Levant sandstone ridges.

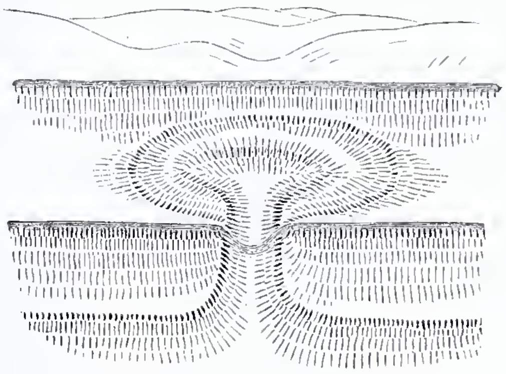


FIG. 758.—Sloping Ravine descending against the Dip.

5. *Gaps or Ravines intersecting Monoclinal Ridges.*—A ravine of this class, in its fullest development, is a deep sloping notch or cleft cutting the ridge to a low level, often to its base.

In many instances the breach is confined to the narrow crest or summit of the ridge, and prolongs itself down each flank in a sloping valley. Such are many of our mountain-passes in the Appalachians. Where it is a thorough cut, penetrating to the mountain's base, and giving passage, as it then so usually does, to some bold stream or river, it is called in Pennsylvania a *Water Gap* and when it indents only the upper part of the ridge, it is termed a *Wind Gap*.

These gaps present sundry minor characteristics, dependent chiefly on the special conditions of hardness and softness in the strata, on their relative dimensions and their steepness of dip, and on the direction of the ravine through the ridge, whether perpendicularly or obliquely transverse.

Where the strata of the mountain possess a very steep dip, the point of greatest contraction in the bed of the gap is only a small distance from the centre toward the dipward side; where, on the other hand, their inclination is comparatively gentle, the narrowest spot is much nearer the end in the same direction. This arises simply from the descent to that side of the hard resisting rocky rib which forms the crest. From this point of least width, where the hard middle rock reaches the water-level, the bed of the pass usually expands trumpet-like in both directions. Upward, the notch dilates, sometimes by steep straight slopes, sometimes by concave ones, and not unfrequently its profile, on one or both sides, is a convex curve.

Many of these gaps in the Appalachian chain are much encumbered on their slopes with fallen blocks dislodged from the edges of the harder rocks ascending towards the summits. Some of these great slanting floors of angular fragments of sandstone—familiarly termed by the people *Stone Slides*—extend from the bottoms of the gaps midway, or even much higher, towards the crests.

The two most obviously distinct varieties of the monoclinal notches are—

1*st Variety: Simple Monoclinal Gaps* in single-crested ridges, where the slopes into the ravine are approximately straight and regular, but steeper or flatter, as the case may be. The essentials to this structure are merely a middle hard stratum, and softer overlying and underlying masses. The most contracted part of the pass is where the hard stratum comes down to the water-level, or bed of the notch (Fig. 759).

2*d Variety.*—Complex or curved monoclinal gaps of steeper or gentler slopes, intersecting ridges composed of five or more alternately hard and soft strata, two at least of which are hard, and form two or more crests. The ravines of this class are oftentimes not straight, but wind with a double or even still more complex flexure through their ridges. If one of the hard formations has exceeded the other considerably in resisting strength, it very frequently throws itself nearly across the opening of the pass in a low ridge or spur breached at one end to the water-level of the other parts of the notch. Such is the feature of the gap in the Mahoning Mountain at Mauch Chunk, and from like causes that of the notch in the Little Shamokin Mountain, at the passage of the Shamokin Creek. At page 29 of Volume I. a pictorial view of the first of these scenes is presented.

Of course, all the conditions of deflection of the outcrops of the strata of the ridge will exhibit themselves in one of these deep thorough gaps, which we encounter in any other level transverse ravine; every outcrop will be turned from its level line, both on the back and on the dipward side of the ridge, and carried down at a more or less abrupt plunge as the dip of the bed and the slope of the ravines may affect it until it reaches the bed or water-level of the notch; there it will cross on a level, in a line parallel to its position on the mountain-side, and reascend the opposite side of the gap in a corresponding sweep, until it resumes its first position on the ridge.

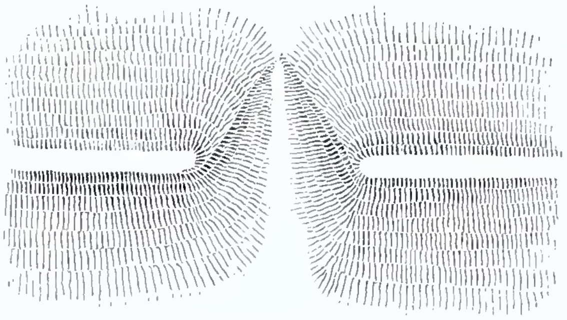


FIG. 759.—Gap in a Simple Monoclinal Ridge.

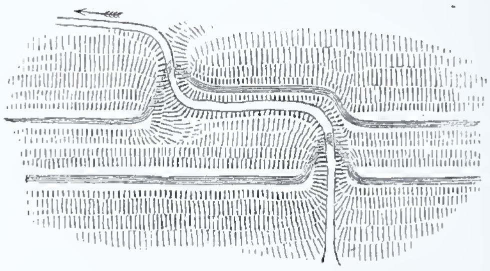


FIG. 760.—Gaps intersecting Monoclinal Ridges.

It seems unnecessary to dwell further on the special features of the ravines of this class, as these have all been considered under previous heads. It remains simply to present a topographical picture (Fig. 760) of one of these gaps.

b. *Longitudinal Ravines in Monoclinal Belts.*

Local longitudinal ravines or trenches in monoclinal strata occur wherever the eroded tract is elevated above the general plain of the country, or intersected by deep transverse channels of drainage.

Thus they abound in the ends of ridges, but especially in the vicinity of the thorough gaps which cleave the monoclinal mountains. Their magnitude and depth will be found to depend mainly on the relative width and softness of the less cohering beds in which they lie, and on the height of the outcrops which they trench above the beds of the valleys and notches into which they descend. They are straightest and sharpest, and most nearly in the line of the strike, where the raised belt of alternately hard and soft strata has a perpendicular or very steep dip. Such is the posture of the rocks in some of the monoclinal ridges of the Levant sandstones between the Susquehanna and the Potomac on the N. sides of the great anticlinal limestone valleys—for example, in the Muncy or Bald Eagle Mountain; and there these longitudinal ravines in the softer Levant middle red argillaceous sandstone and shale are very conspicuous features in the orography. Where, on the other hand, the inclination of the beds is less, the ravines do not descend in the line of the strike, nor are they straight, but they follow the dip, as we have already seen, and usually with more or less of curvature. In both cases they are but prolongations of the horizontal terraces or benches which are deflected partially, but not exactly, in the direction of the dip, from the circumstance that while the erosion has followed in great part the softer strata, the eroding descending currents have at the same time been rushing somewhat more directly down the hill-side in obedience to their gravity. In the instances where the inequality in the firmness of the materials is at all excessive, and where both kinds are comparatively thick, conditions which prevail in the lower Coal-measures, or Seral conglomerate group, around the margin of the Shamokin coal-basin, these obliquely-descending ravined benches are separated by more or less boldly-jutting craggy ribs or ledges of the alternating harder rocks, which in the gaps of the Shamokin basin are massive, tightly cemented, coarse silicious conglomerates and sandstones, the interposed softer measures being coal shales and thick beds of friable anthracite.

It is not needful to dwell longer on the features of local longitudinal erosion, since all the essential phenomena have been described either in this paragraph, or in preceding ones treating of the modifications of the "transverse ravines."

I pass next to the various kinds of local denudations incident to anticlinal belts, especially to anticlinal ridges.

VII.—ANTICLINAL RIDGES.

a. *Local Erosion of Anticlinal Ridges.*

The first case is that of erosion upon the descending ends of anticlinal ridges, curving the denuded outcrops of the strata in a convex sweep round the subsiding spur, from one flank to the opposite across the axis, and presenting the terminating inflected lesser crests and terraces in sharper relief than where these are prolonged on the sides of the ridges. In the phraseology of the anthracite region, such outcrops, or the gangways below them, are said to "wind round the ends of the saddles."

b. *Gaps or Notches in Anticlinal Ridges.*

The features of these gaps are variously modified by the nature of the strata transversely breached and eroded.

1. One variety is where the whole of the interior rocks of the anticlinal, from the axis at the water-level to the crest of the ridge, are hard and cohering, and the flanking strata comparatively soft. In this case the gap is usually a simple trough-like cut (Fig. 761), with more or less steep plane-slopes, and is narrowest in the middle of the gorge, widening in trumpet-shape towards either base of the ridge or mountain.

2. Another variety is where there are three sets of rocks in the ridge, the arching crest ones hard, and the inner lower set at the axis soft for some height above the water-level, or bed of the notch. In such case the form of the gap is more complex, being dilated and circular or oval in the centre, and contracted towards either outlet by the obliquely-descending converging ribs of the hard formation. Where the hard rocks span, as they often do, the whole anticlinal, in one unbroken majestic arch of craggy precipices receding in a semicircular sweep at the crown of the curve, and approaching closely as they plunge on either flank to the level of the pass, we have the simplest, but perhaps the most picturesque, of all the forms of oval anticlinal valleys. These are the cluses of the Jura chain of Switzerland, where, composed of massively-bedded limestones, the finest of cliff-forming strata, and being of grand height and span, they constitute some of the most impressively wild and beautiful natural amphitheatres which water has anywhere carved out of rocks. In some instances the great rocky arches on each side of the pass are nearly a mile in span, their precipitous walls are many hundred, or even a thousand, feet in vertical height; and from the base of their beetling crags descends on each side a very long and concave mountain-slope or *talus* of huge fallen fragments of the cliffs, bringing down the ruggedness of the upper scene to the very margin of a smooth verdant meadow or oval plain. This stretches the length of the notch, is watered by a sparkling river, enlivened by a furnace or a mill, and is shut entirely in from the outer country by the jaws of a contracted rocky gorge or mere gateway, leading into and out of it between towering, jagged, perpendicular crags, which, in several cases in the Jura, are crowned by the fitly-placed ruins of some old baronial castle, or "feudal robber's nest."

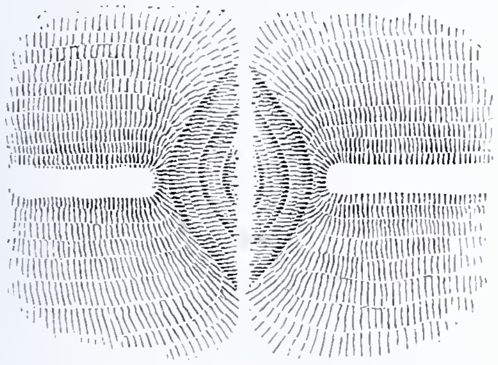


FIG. 761.—Gap in an Anticlinal Ridge of hard strata.

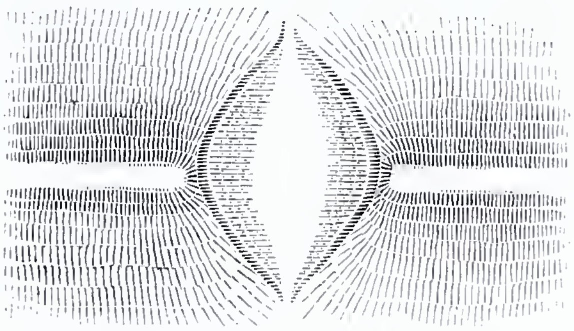


FIG. 762.—Gap or Oval Pass in an Anticlinal Ridge, the lower stratum being soft.

In the anticlinal passes of the Appalachians, this species of mountain-gap, in virtue of the greater hardness of all the strata, and the absence of limestones as the mountain-rocks, is decidedly more tame in its scenery, but its constituent features are essentially the same as those I have here described as characterising the passes of the Jura Mountains.

The accompanying cut (Fig. 762) is an illustration of one of these oval passes.

A modification of this form of notch in an anticlinal ridge, somewhat frequent in the Appalachian chain, especially between the Susquehanna and the Potomac, is where the breach is not entirely through the mountain, but is confined to one side of it; or, what is the same thing, to one abutment only of the arch. The oval valley called Mosquito Cove, in Bald Eagle Mountain, and even the longer and more open elliptical Nippenose Valley in the same ridge, may be cited as cases of this sort. They are deep oval hollows scooped in a broad flattish anticlinal mountain by whirling waters, which cut for each but a single outlet through the N. or steepest, thinnest, and most shattered abutment of the arch. Many others of this type occur as high oval valleys on the backs of the anticlinals, not only in both the Appalachian and the Jura, but in other undulated chains. One instance is the small mountain-valley midway along the crest, in the highest part of Tuscarora Mountain, on the line of Perry and Juniata counties, Pennsylvania. A lateral gap of this sort, breaching only one of the monoclinal barriers or wings of an oval valley of denudations, is called in Switzerland a *ruz*, in contradistinction to a *cluse*, which is a double gap cutting the whole arch. Between these anticlinal gaps and the elongated oval anticlinal denuded valleys, there occur examples of every intermediate form, from such as are mere narrow transverse notches at their bases, through the transverse oval, and the nearly circular kettles, to the longitudinally oval valleys in all proportions; and it will be found, on generalising our survey of them and their attendant features, that they are all the offsprings of the same conditions of structure and the same physical forces—namely, a transverse rupturing by one or several cracks of the most distended parts of the anticlinals, and the passage of tremendous sheets of water across the ridges, and through the weakened and ruptured lines where the currents were necessarily deflected into irresistible vast excavating whirlpools by the obliquity of the barriers encountered or produced.

Thus it has come to pass that so many of the more largely excavated oval anticlinal valleys in the Appalachian chain between the Susquehanna and the Potomac, both the narrow high ones of the anticlinal ridges and the deeper wider ones exposing the soft Matinal and Auroral rocks, are provided with more than one pass through or into them. In fact, the number of the notches which give access to them is very various, from a single gap or depression confined to one, and that always the weaker side, to a thorough-cut or gap in both barriers—the normal type of these mountain-passes—or to even several monoclinal openings, sometimes all of them in one, sometimes in both barriers. An inspection of the topography of the mountain-chain S.W. of the Susquehanna will show these notches, both in the anticlinal ridges and in their monoclinal branches, in a great variety of combinations and situations.

It will be seen how very frequently a notch occurs—especially the single ones, or those in the monoclinal ridges—*near the ends* of the longer class of denuded anticlinal valleys. The causes of this prevalence of position, and of the still more marked excess in the number of these openings in the Northern over those in the Southern monoclinal barriers of the valleys, will appear distinctly in a future chapter, where an attempt will be made to discuss fully the mode of action of the forces which undulated the strata, and which, in arching the anticlinals, rifted them transversely, and most frequently and severely, towards their subsiding ends.

3. Another and distinct variety among the passes or gaps in anticlinal ridges occurs where there are FOUR or more separate sets of alternately soft and hard cohering strata, the lowest rising at the axis above the bed of the notch or valley in an interior arch, while the third rock, or upper hard one, still spans the breadth and height of the ridge, only covered low on its flanks by the softer and uppermost of the series. In this case, when the denudation is regular, as it is apt to be where the anticlinal wave is broad and of gentle curvature at the summit, we have an oval or circular deep cavity in the mountain, with a narrow outlet at one or both sides, just as in the variety previously described; but some of the internal features of the gorge are essentially different. The same semicircular steep cliffs or concave slopes sweep round each side of the amphitheatre, ascending and receding from each other with the climbing of the arch, and redescending and approaching again with its curving downward to its opposite abutment; but the *talus*, or long concave inclined plane of blocks and fragmentary rubbish dislodged from this steep upper encircling wall or slope, and covering the underlying softer stratum on each side of the notch, does not here descend to the bed of the valley, but only to the top of the second or interior arch formed by the hardness of the lower rocks, exposed in all the gaps of this class, in the centre or axis of the anticlinal. In mountain-passes of this form, the grand enlarged amphitheatre of the higher harder rocks is lifted, as it were, on the back of an inner and lower anticlinal ridge, which is itself transversely breached or notched to the water-level in the centre. This inner anticlinal arch repeats, often on a scale almost as large, the shape of the variety of anticlinal pass first specified (Var. **b.** 1), which is that of a simple trough-like cut, narrowest in the very middle of the pass, and expanding trumpet-like towards either side; but exterior to it, yet still within the mountain, is the great encircling oval or circular valley, with its talus on each side, and its double semicircle of cliffs or high craggy slopes lifted on the back of this interior saddle, and filling the span of the mountain. The ground-plan of the bed of an anticlinal pass of this description—where the denudation is synclinal, as in some cases it is, especially in the Jura—bears no remote resemblance to two lancets united at their shanks, or to the double-leaved paddle of an Esquimaux's canoe. Expanding from the middle of the hard inner arch in both directions, and widest at each side of it, where the easily-denuded softer strata descend both ways to the level of the gorge, the two ends are pinched again by the descent and convergence of the great outer upper arch of hard material, until, in some examples, they become merely the narrowest defiles, allowing space for only a stream and a roadway before they dilate into the open plains outside.

Instances of this class of notches in anticlinal ridges are not unfrequent in the Appalachian chain. On a relatively reduced scale they are even common in the anthracite coal-fields of the Schuylkill and Shamokin basins; but for the best-defined, most symmetrical, and most picturesque examples of this class, we must again turn to the limestone ridges of the Jura (Fig. 763).

4. There yet remains to be described a fourth modification of the anticlinal pass, or oval mountain-notch; it is where the anticlinal ridge or mountain embraces five sets of strata of different susceptibility to erosion—the *first* or lowest, the *third*, and the *fifth* being shales, or slates, or other soft rocks; and the *second* and *fourth*, sandstones or other firmly-cemented and resisting formations (Fig. 764). A gap or valley of this description differs from those of the type last defined only in its innermost or central features, which in that variety were those of a simple trough-like cut or notch in a central anticlinal arch of hard materials, but which in this are the features of the second type of anticlinal gaps or simple cluses repeated over again, but enclosed within a larger higher cluse or amphitheatre, saddling and embracing the inner and lower one as a larger conical oval funnel with a vertical upper rim would embrace and rest above a smaller similar funnel inserted in its truncated conical apex.

It is a circular or oval pot, opening upwards into a wider and higher circular or oval pot, whose bottom and upper lip or rim are neither of them flat or in a horizontal plane, but saddle-shaped or arching. Of course this form, where it is on a large and perfect scale, presents all the elements of scenery of the preceding or third variety of anticlinal pass in the upper and enclosing amphitheatre, with all the features characteristic of the second, in its lower interior or central cluse or valley; for this latter, when fully developed, as it is in one or two very striking instances in the Jura chain, has on either hand the encircling arching precipice, the long steep concave talus, or rugged " stone slide," and the smooth more or less dilated oval plain between in the bed of the notch. In the Appalachian anticlinals, between the Susquehanna and Potomac, and in Virginia, nearly all the examples of this concentric or double denudation, on the large scale, are cases of elongated anticlinal valleys of erosion of the type described (page 933) as of the group **b**, second variety, so common where the erosion has reached the Matinal and Auroral rocks. Even where these valleys have a gap at each side in their monoclinal barriers, as in the instance of Friend's Cove, in Bedford County, Pennsylvania, their great length in the direction of the anticlinal axis removes them from the class of mountain notches or passes, or that even of expanded cluses, though in reality they retain all the features of these at their two withdrawn extremities, and are to be viewed in a structural light as but extreme extensions of the same elements, and the products of the combined action of the same whirling erosive currents and crust-undulations—differing in degree, but not in kind—in the extent of the denudation along the anticlinals, and not differing in the nature of the actions, or the relations of the strata acted on.

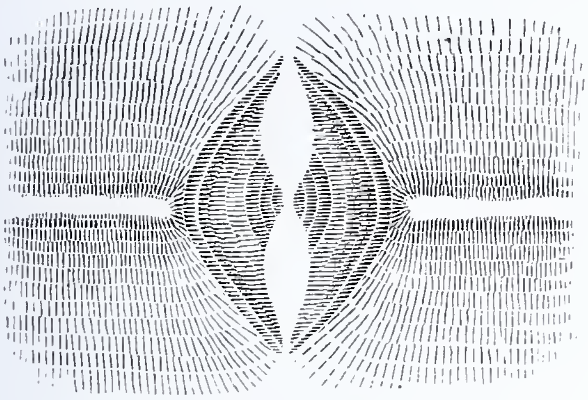


FIG. 763.—Gap in an Anticlinal Ridge. Complex variety arising from two hard and two soft strata.

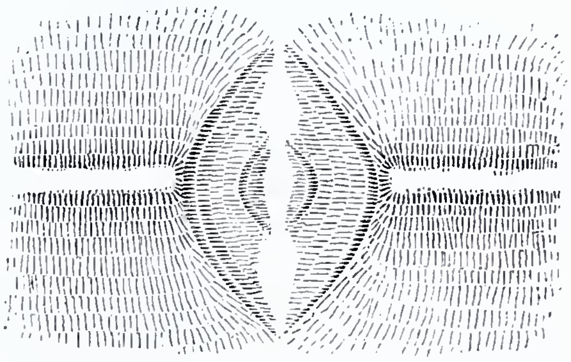


FIG. 764.—Gap in Anticlinal Ridge. Complex variety, produced by three soft and two hard strata.

The features of the four several varieties of anticlinal notches or circular gaps, above described, are much modified in their pictorial characters, first by the qualities of the strata eroded, and, secondly, by the style of the anticlinal curve. Their impressiveness or their tameness, as the case may be, will be found to be mainly connected with the greater or less difference of liability in the strata to erosion or degradation by water; but the degree of such susceptibility, let it be observed, is not dependent solely on differences of cohesion between the particles, or on mere hardness or softness, but is materially influenced by other conditions also, especially the absence or presence of joints and cleavage fissures, affording a grasp to the waters, and by the less or greater destructibility of the fragments torn away from the outcropping beds. Each region, therefore, however similar to others it may be in its undulated structure—in the form that is, of its anticlinal and synclinal flexures—will yet possess some distinctive characters in its scenery, some peculiar tone in its landscapes, even where these contain the elements of construction, traceable on examination to one or more of those circumstances that control the cutting and removing power of the waters in their action on the rocks. And these minor features of expression, so apt, from their very uniqueness, to lead away the attention of the student of nature from the generic identity of the scenes with others of their class, are especially distinctive in the gorges and passes of mountains, where whatever is individual to the region, in the composition of its rocky framework, will, from the stronger conflict there of the eroding and resisting agents, be all the more conspicuously developed. Therefore it is that the points of dissimilarity in the rocky constitution of the Appalachian and the Jura chains, so analogous in their general dynamic structure, or features of undulation and rupture, are most obvious precisely in these mountain gaps and clefts, whose construction, class for class, is so identical in the two mountain-regions. In the Appalachians the different features melt more into each other, and the whole scenery is tamer than in the Jura, because, in the former, the sandstones and slates of the ridges, and limestones and shales of the valleys, are less contrasted with each other in facility of erosion, than are the massive limestones of the latter chain, with its soft marls and clays. Besides, all the rocks of the Swiss chain are softer, and far more easily trenched and denuded, than the corresponding ones of the American range. Indeed, the valley-rocks of the Appalachians are altogether as difficult of erosion as are the mountain or harder masses of the Jura; they are, in fact, of the same chemical nature—limestones chiefly in both instances. If any difference does prevail, it is a superior cohesion on the side of these Appalachian softest formations over those Jurassic hardest ones, the one group being tough sub-crystalline limestones and indurated sandy slates of the Palæozoic age, the other compact and earthy limestones of the Oolitic period. This difference of resisting strength in the strata has evidently been of itself a most influential source of the sharper and deeper excavation of the Jura anticlinals, and of the consequently higher picturesqueness of its scenery. But it has been stated above that the topographical features of a denuded mountain-zone depend no less on the character or style of its anticlinal or synclinal flexures, than upon any or all of these relations of the strata to each other affecting their relative vulnerability to erosion. To a brief review of the influence of this element of form in the crust-undulations I will now proceed.

It is obvious that the shape or style of the anticlinal curve or sweep of the arch which the strata span, must of necessity modify more or less the form and structure of the notches and oval valleys carved in the ridges by the waters. These convex flexures possess, as we have seen, very various styles of curvature, some of them being nearly symmetrical waves, while others are of unequal incurvation on their opposite sides, having, like the billows which roll in over a constantly-shoaling bottom, a steep and a gentle slope. They have, moreover, further differences; in the comparative flatness of the summits of some waves, and the more angular turn of others at the crest or axis; and these important variations belong to both the symmetrical and the unsymmetrical groups. Now it needs very little reflection upon the forms which must result from the intersections of differently-curved solids, to show us that each series of circular and oval excavations in these dissimilar kinds of anticlinals, will necessarily receive from the special characters of their curves special subordinate modifications of their distinctive structural features. Thus, where the wave is both symmetrical and gently rounded on its back or crest, the hollow scooped within it will approximate to a regular oval or a circle; and the rim of the pot-like valley, and those of all the terraces within it, if it be excavated in an alternating group of soft and hard strata, will be approximately horizontal. While if, on the other hand, the wave is sharply crested, the denudation will result, not in two evenly-curved semicircular or half-oval valleys, one on either side of the transverse notch, but in two ascending and sharply-pointed valleys, making together a rhombic or diamond-shaped hollow, longest generally in the direction of the ridge's crest. And again, where, with either of these conditions of flatness or sharpness of summit, the anticlinal wave is unsymmetrical, or bends more or less steeply down on one side than on the other, there is a proportionate departure in the gorge or valley from either the regular circular, the oval or the rhombic figure, the side carved out of the more inclined flank of the wave being invariably and necessarily straighter and lower than the opposite. Such is the very general character of the hollows, whether mere notches or long denuded valleys in the anticlinals of the Appalachians; and such, indeed, will be found to be the very prevailing type of the pot-like gaps and valleys eroded in anticlinal ridges in all mountain-chains.

We have in the deep water-gap of the Juniata River, at its passage through Jack's Mountain, in Huntingdon County, Pennsylvania, a very good example of extensive denudation on the crest of a rather sharp and unsymmetrical anticlinal mountain-ridge. Here the S.E. flank of the wave is gentle, dipping about 30°, while the N.W. is at its abutment almost perpendicular. The crest is, moreover, abruptly turned. The denuding waters working upon this form, through the four successive great strata which build up the mountain, two great hard and massive sandstones, and two softer argillaceous strata, a hard one at the summit, and a soft one at the base in the axis of the ridge, have carved a great anticlinal hollow or rude cluse of the *double type*, in which each lateral recess or cove is pointed or angular in the direction of the crest, rather than rounded or oval, as it would have been had the curvature of the top of the wave been more flat or gently rounded. Being of the fourth variety of anticlinal notches described by me, where there are two hard formations, each to send down its two projecting spurs to the water-level, to make, when perfect, an outer and an inner amphitheatre, and in this case the arch being deeply cut to its abutments, and the inclinations of its sides being steep, there stand out four separate ridges, coming down from either mountain end toward the middle of the pass at the river.

VIII.—FEATURES OF LOCAL EROSION OF SYNCLINAL BELTS.

a. *Erosion of the Ends of Synclinal Ridges.*

The extremities of elevated synclinal belts, both ridges and narrow plateaus, are very generally much denuded, especially where the materials forming the base of the ridge are comparatively soft, as in that case their deeper excavation, by causing a superior steepness in the sides and ends of the ridges, has given to the final local currents a greater perpendicular pressure in rushing down the slopes.

Two features of erosion of the ends of such ridges are worthy of attention.

1. *Truncations of the Ends of Synclinal Ridges.*—A very common mode of ending of the ridges of synclinal structure, is by an abrupt cutting-off or truncation of their tapering points. Where the denudation of the mountainous zone has been very equable or chiefly longitudinal, the raised synclinal belts taper gradually off, both in width and height; but wherever strong transverse currents have swept across the terminations of such ridges, these are sure to be thus abruptly, and more or less squarely, cut away. In these cases the synclinal ridge, usually forming the ending of a mountain trough or basin by the coalescing of two monoclinal barriers, rises above the general level of the monoclinal crests into a high terminal knob, the crest-line of which suddenly gives place to a steep transverse slope, cutting the mountain from this high point to its base. Such is the feature in which the Terrace Mountain, near Huntingdon, ends against the valley of the Juniata; and very similar is the termination of the Mahanoy Mountain, on the Susquehanna. Many other examples could be adduced from the Appalachian chain in Pennsylvania and Virginia.

This abrupt arrest of the synclinal ridges is in striking contrast with the beautifully gentle and gradual tapering and curving down of the expiring anticlinal crests; and the erosive conditions productive of the two phases were not less dissimilar. In the instance of the synclinal belts, the waters were enabled, by the rising out above the general water-level of the country of the lower softer strata, to exert against them, just where least protected by the overlying firmer rocks, their fullest amount of excavating power, resulting in a tendency to steep cutting, or even, in certain cases, to absolute under-cutting, from the everywhere inward dip of the strata. But in the opposite case of the anticlinal belts, the harder crest-rocks of the ridges buried and sheltered the softer subjacent beds, and the more effectually the nearer the terminations of the crests, thereby giving the form of the anticlinal wave itself a constantly-increasing influence, and the erosive force of the water a diminishing one, to the end of the axis. It is only necessary to compare the profiles or crest-curves of the synclinal and anticlinal mountains exhibited in the illustrations in this work, to perceive at a glance the remarkable and characteristic differences of outline left by the waters on the ends of the two kinds of waves.

2. *Longitudinal Erosion of the Ends of Synclinal Ridges.*—In many instances the ends of synclinal ridges, and narrow synclinal table-lands, are much gashed by sharp sloping ravines. Where the crest is narrow, and formed by steeply-dipping hard strata, these trenches, scooped in the ends and flanks of such ridges, often radiate downward quite regularly in a sort of fan-like arrangement from the terminating knob. A feature of this kind presents itself in the terminal spur of the Shamokin coal-basin, seen from the W., from near the mouth of Zerbe's Run. It belongs likewise to the similar spur prolonged from the Wiconisco Coal-basin, and is more or less characteristic, indeed, of the synclinal spurs of the anthracite coal-basins generally. Where, on the contrary, the ridge is not a mere narrow crest, but a slender table-land, truncated, as such generally are, at its extremity, these ravines are confined more strictly to the end, and are more truly longitudinal in their direction. The narrow plateaus composed of the lower Levant sandstone, supporting the Levant red shale, which form so striking a feature in the great anticlinal limestone valleys of Centre and Mifflin counties, especially those in Kishacoquillas Valley, present us with fine instances of this terminal ravining, showing most unequivocally how the last localised currents of the retreating waters rushed lengthwise down the newly-truncated ends of these picturesque terraces. A glance at the picture of the Kishacoquillas ridges (Vol. I., page 476), looking E., will make this feature understood.

b. *Erosion of the Ends of Synclinal Valleys.*

The characteristic or usual form of the head or end of a synclinal trough—such as the termination of one of our wider coal-basins, the Shamokin, for example—is that of a symmetrically spoon-shaped valley, ascending at its very extremity to the level of the bounding converging crests. But this regular structure is departed from in many instances, by the presence of features of local erosion, which it is proper here to advert to. These, as in the denudations of synclinal ridges, are both transverse and longitudinal.

1. *Transverse Denudation of the Ends of Basins.*—A not unfrequent termination of a synclinal valley, bounded by narrow ridges of steeply-dipping rocks, is by an open longitudinal pass, caused by the entire obliteration of the synclinal ridge or knob which ordinarily forms the end of the basin. The destruction of the prow of the boat, and the scooping out of its contents at the broken end, must be imputed, in most instances, primarily to some great transverse fault or fissure weakening what is usually, from the close convergence or union of the monoclinal bounding ridges, the most massive and strongest portion of its rim. The cutting away of the dislocated end by a powerful transverse current would be necessarily followed or accompanied by the sweeping of a lesser longitudinally deflected lower current through the jaws of the newly-opened gap. Thus it has arisen that such truncated ends of basins are often deeply eroded, and their contained softer rocks—a body of coal-measures, perhaps—are almost completely washed away from the bed of the trough. There are several cases of this kind on a small scale in the anthracite region, and some approximations to it among the larger basins. The extremity of a synclinal valley, so nipped off and scoured out, resembles much in form as, at the time of its final shaping, it did in actual function, a great *spout*, like that of a pitcher. The W. end of the Wyoming Basin at Shickshinny is an example of both transverse and longitudinal erosion.

2. *Longitudinal Erosion of the Ends of Basins.*—It has just been shown that a longitudinal erosion, or scooping out of the end of a basin, accompanies generally its truncation; but it also occurs in cases where the termination is not abruptly nipped off, but only extensively worn down, as happens when the protecting harder rocks have been of

insufficient firmness to withstand the longitudinal currents through the valley. This feature prevails usually where the synclinal dips are rather gentle.

3. *Features of diffused Erosion of the Ends of Synclinal Valleys or Basins.*—The precise form in which a basin composed of hard strata, supporting and embracing softer ones, usually terminates, depends mainly, of course, on the two elements of the dip of the beds, and their relative degrees of resistance to erosion. In the simplest case of three formations—a-middle-hard one, forming the rim of the synclinal valley, and a soft lower, and another soft upper, deposit—all carved into a mountain-trough standing above the general level of the outer country, the more gentle the dip, and broader the synclinal wave, the rounder or blunter will be the outline of the spoon-shaped end of the basin; and the steeper the dip, the more slender. The anthracite fields of Pennsylvania present numerous examples of both of these types, and display this connection perfectly. Where the strata are synclinal at a moderate angle, and their dips on the two sides of the axis nearly equal, and where the synclinal line or keel of the boat rises perceptibly or considerably, we will find, if there exist no terminal nor lateral gap, the nearest approach to perfect symmetry in the beautiful concave oval sloping valley. While such is the contour of the interior of the basin carved out of the soft upper strata, that of its rim or barrier is a curve-line surface of not less grace. The converging monoclinal bounding ridges, gradually expanding and rising in their crests as they swing into each other to enclose the head of the trough, form, where they blend together to fill the synclinal space, a most noble and peculiar style of mountain swell; an elevated, ample, egg-shaped knob or summit, higher considerably than the monoclinal crests, keeping high watch over the comely valley which it terminates, and a still loftier outlook over the external country. Gracefully and largely convex in all its upper lines, this terminal synclinal hill, when regular, invariably sends downward into the exterior plain or valley in which it rests, a series of concave flattening and dilating slopes, which are no less marked for their ampleness of sweep than the exquisite delicacy of their flowing curvature. The highest and widest point of one of these knobs is generally not in the centre of its length, but nearer the basin which it closes up—precisely as the broadest and highest point of an egg resting on its side is between its centre and its blunt end. Summits of this description, of course, send off a declining spur, more or less pointed, in the direction of the synclinal line, and branch into the two other directions of the monoclinal crests, out of the union of which they arise.

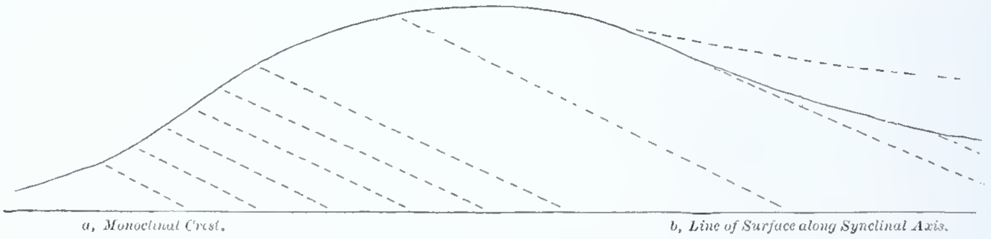


FIG. 765.—Profile of a Synclinal Knob.

The profile or longitudinal contour-line here presented (Fig. 765), will serve to aid the conceptions of the reader, not familiar by close observation with the structure of the Appalachian chain. It is a perpendicular section of the end of a basin along the synclinal axis.

c. *Local Erosion of Synclinal Belts, connected with transverse Gaps or Notches.*

Just as in the instances of the breaching of anticlinal ridges by transverse notches, give rise, under different phases of uplift of the anticlinal wave, to different forms in the gaps, so in the several types of synclinal ridges and raised basins we meet with special modifications in the notches by which they likewise are cleft. As the gorges of this class are, however, of more rare occurrence than the anticlinal ones, except perhaps the simplest varieties, and as there is less that is remarkable in their structure demanding detailed description, it will suffice merely to indicate their several features, and the conditions under which they have been produced.

1. *Simple Gaps in Synclinal Ridges or narrow Plateaus, composed of a harder Series of Strata reposing on a softer.*—Though all of the notches of this simplest and most common class have a generic form and one definite character, the proportions and scenery of their parts are modified by the special circumstances of the dip of the rocks, and their relative thickness and degrees of cohesion. The essential features of such gaps are these. The opposing ends of the ridge, which form the slopes or jaws of the notch, approach nearest in the middle of the gap, and round rapidly off at their sides both *outward* and *upward*—the converse of the converging arching of the harder belts in the cluses or oval gaps of simple anticlinal ridges. This style of pass is to be met with occasionally in the narrow plateau basins of the anthracite country of Pennsylvania; that of Rattling Run in Broad Mountain, opposite Ashland, is nearly of this structure. No sketchis needed to assist the conception of this simple structure.

2. *Complex Gaps in Synclinal Ridges or narrow Plateaus.*—These exist in their most completely developed character where the ridge or plateau in which the notch occurs, consists of at least four alternately hard and soft groups of strata. If the dips or basining be considerable, and the cleft, from the easy erosion of the softer strata, be sharp and steep, this form of gorge which under these conditions is invested with its boldest and most distinctive outlines, displays often a scenery of much picturesqueness. The extent of its pictorial beauty and impressiveness will depend largely, however, on the character of the harder strata intersected in the pass, as on their being vertically jointed and craggy, like many varieties of limestone. If they are susceptible only of rounded surfaces of erosion, like many of our tough, cohering, silicious conglomerates and sandstones, the defile will be deficient in wild grandeur.

The complex notches here referred to, cutting several alternating hard and soft strata, are a species of terraced gaps, in which all the formations exposed endwise by the denudation display inverted arches or trough-like curves, the hard ones in precipitous walls or steep slopes, as the nature of the materials determines; the softer beds, in gentler, talus-covered, slanting platforms of various inclinations. Conversely to the *receding rising* sweep of the upright arches of harder strata in the anticlinal gaps, the same harder beds, in these inverted arches, *approach, descending,* towards the centres of the synclinal notches. Hence, a structure of cliffs and slopes, or of steep slopes and terraces, ascending and retreating outward in both directions from the middle of the pass, until they curve round and upward into the flanks of the ridge or plateau.

A configuration of this sort is not at all rare, on a small scale, in the ravines which cross the narrow subordinate basins in the Great Pottsville and Shamokin coal-fields. In our Pennsylvanian mountain-ridges and plateaus it is of less frequent occurrence.

This structural feature is to be seen, but not in the conditions of proximity, to constitute a mountain pass or gap in the relations of the two opposing terraced spurs of the N. side of Kishacoquillas Valley, as the map and the sketches in this work will show. A clear conception of the essential features of these complex synclinal gorges will be found to be serviceable in tracing coal-beds and other strata from the flanks of synclinal ridges into and out of the gaps which intersect them.

d. *Lateral Gaps and Breaches in Synclinal Basins.*

It has been already shown that the Anticlinal Valleys of the Appalachian and other mountain chains, and the anticlinal notches likewise, both frequently exhibit gaps on one side only, or in but one abutment of the arch. Such of these gaps as appertain to the larger valleys have been described as monoclinal notches, while those connected with the shorter transverse excavations have been alluded to under their Swiss name of *Ruzes.* Among the local erosions of anticlinals, corresponding monoclinal notches and ruzes occur in the barriers of the synclinal valleys, and in some of the more local erosions in synclinal *cirques.* No further special allusion need here be made to the more ordinary variety in the central portions of the monoclinal rims of the mountain-basins, for they are but one series of the common monoclinal gaps; but a more distinct mention is demanded of the class of these breaches situated very near the ends of the synclinal valleys, high on one or other of the bows of the boat. To these latter, and to the lateral notches in the oval synclinal cirques, we shall therefore now give our attention, and to those of the cirques first.

1. *Lateral Gaps in small oval Synclinal Valleys.*—From the prevalence of a very elongated form in the crust-undulations of the Appalachian chain, the instances of short oval synclinal valleys or kettles wholly enclosed, or breached only on one side, are comparatively rare. The chief part of those met with are cirques, denuded in an upper series of soft rocks by virtue of a local whirling and scooping action of waters, deriving their power from a crack or breach in one rim or barrier of a long narrow mountain-trough, and not in a short one. Yet a few, under the latter circumstances, do occur, and these are the equivalents, under a converse structure, of the anticlinal single-notched cluses, or monoclinal gaps entering anticlinal cirques. Their essential conditions are, a short oval basin or synclinal mountain-valley, composed necessarily of three sets of strata—a soft external lower series; a hard middle one, forming the oval mountain-lip of the basin; and a soft upper series enclosed within the valley, denuded through the opening in one side of the rim. A considerable degree of synclinal dip on one side at least of the axis is indispensable to the existence of this structure.

Of examples, we may mention McCauley's Mountain, a small insulated elevated coal-basin near the Catawissa Valley. It is a short mountain-trough of shallow anthracite Coal-measures, girt by a rim of the hard Seral conglomerate, breached by a steep ravine or crest-gap on the S. side, where the dip is steep, and the barrier was consequently comparatively weak against the general rush of waters from the N.W.—(See the Geological Map of the Anthracite Region.)

Another instance which may be cited as belonging, perhaps, most appropriately to this class, is that of Scrub Ridge in Bedford County, a somewhat elongated mountain-basin of the soft *Umbral red shales,* supported within an oval barrier of hard *Vespertine sandstones.* Here likewise, in accordance with the prevailing law of the Appalachian flexures, the S.E. barrier of the synclinal trough is steeply dipping, and is therefore the side which has been breached; the breach in this case being not in the middle, but near the S. end.—(See the General Geological Map.)

2. *Lateral Gaps or Breaches at the Ends of Basins.*—These have been already alluded to as occurring high on the bow of the boat. Their very general position in the Appalachian chain, as seen extensively in the anthracite basins, is on the S.E. or S. side; and this from an obvious cause, before adverted to—the superior steepness, and consequent slenderness, of the outcropping strata of that margin. Frequently these outlets in the lower more denuded S.E. wall of the basin are not narrow deep gaps or gorges, but rather long and ragged breaches, such as that in the E. end of the Pottsville basin in Sharp Mountain above Mauch Chunk, and that in the S.W. end of the Shamokin basin, three miles from Trevorton. Such breaches are usually worn down to the high level of the bed of the valley within; but as the enclosing mountain-rim is under this proximity to the head of the basin, invariably of small altitude above this bed, the notch-like depth and form do not exist. On the exterior of the mountain, the breach prolongs itself down the flank in a wide and more or less deep ravine or great gulley, the channel through which the currents making the break in the barrier above carved their course to the plains outside, carrying with them the wreck of much of the coal strata of the head of the basin, and that of all the other rocks that lay across their track.

In other instances, confined mountain-notches do occur, near the extreme ends of the basins, especially in the anthracite region ; but these, as in the examples of the Bear Gap of the Wiconisco Basin, the W. gap of the Mahanoy basin, and others, exist only where the monoclinal barrier breached is strong and massive from the moderate degree of dip of its hard strata. In all such cases there is likewise an external gulley or great trench, prolonged from the bottom of the gap down the slope of the mountain, and even in these instances of deeper notching, the height of this ravine, or difference of level between the coal-basin above and the outside valley of Umbral red shale below, amounts to several hundred feet.

There is yet another modification of this lateral outlet at the ends of synclinal valleys, examples of which are to be recognised in the anthracite country. It is where there is no positive notch or even shallow breach in the barrier of the basin ; but a rising up of the bed of the spoon-shaped trough to the very level of the mountain-rim, or a general cutting-down of this to meet the high point of the basin, and on the outside of the mountain a trench or ravine through the hard barrier-rocks, and its lower softer strata down to the external plain. Such is the E. termination of the South Mahanoy Coal-basin, where the ravine of Pine Creek is exterior to the rim of conglomerate, and does not notch it ; and such very nearly at least is the outlet at the extreme Western end of the Mahanoy basin, where the old Minersville Road passes across the tip of the basin, and over, but not through, the S. boundary of conglomerate, and down the exterior mountain-side through a long ravine, to a lower level of several hundred feet.

e. *Modifications of the Phenomena of General and Local Erosion dependent on wide Deviations from Symmetry of Structure in the Anticlinals and Synclinals.*

In the preceding sections of this chapter on the General and Local Features of Erosion, those phenomena chiefly were considered which have resulted from the erosion of symmetrical anticlinal and synclinal belts, or such as possess approximately equal degrees of incurvation, or of dip on both sides of the axes. It was felt that it might complicate too much the description of structures not very easily made intelligible in words, even with the most methodical treatment, to give the abnormal or deviating forms dependent on unsymmetrical flexures, under the same heads with the regular ones, and that the reader's conceptions would be clearer if they were reviewed in a group by themselves.

A strictly exact symmetry in the external features of the ridges and valleys, and their gaps, can of course nowhere prevail even under the most equable conditions of the erosive action ; for, as already shown, the undulations of the strata, which determine the whole character of the orography, are very seldom, if ever, themselves equilateral—that is, symmetrical on both sides of their axes, or highest and lowest points. But a moderate amount of inequality in the two slopes of the waves is not usually productive of any very striking topographical irregularities ; and as such moderate inequality is really the normal condition of the flexures of the crust, the features arising therefrom have been viewed as regular. Only the wider departures, therefore, from this merely approximate equilateral symmetry of the denuded anticlinals and synclinals, connected with the more extreme aberrations from an equal balancing of the dips, will be here submitted to review. For the sake of greater precision, the normal or only moderately inequilateral flexures may be here defined as those in which the average difference in the two sets of dips does not exceed 25° or 30°, as when the one side dips 30° or 40°, and the other 60° or 70°, and all waves of more unequal slopes than this are to be viewed as inequilateral, and productive of unsymmetry in the topography. These may be classed and described as follows, restricting our attention to the more characteristic only of the abnormal forms immediately connected with anticlinal and synclinal belts and their accidents. After the foregoing full account given of the various regular forms of external structure, these less symmetrical ones need not detain us long.

IX.—DENUDATION OF UNSYMMETRICAL ANTICLINAL BELTS.

The anticlinal tracts, in which there prevails a marked inequality between the dips of the opposite slopes of the waves, may, as respects their features of denudation, be conveniently divided into such as are simple ridges, and such as are elevated belts, denuded along their axes into valleys.

a. *Erosion of Unsymmetrical Anticlinal Ridges.*

All anticlinal ridges, whether curving or straight, will be seen, where there is a very obvious excess of steepness in the dips of one flank over those of the other, to have the anticlinal line or axis not in the orographic crest, but more or less down on the steep slope of the side of greatest dip, and therefore often not far in horizontal distance from that base. And they may be observed, furthermore, in their declining ends, still carrying the axis more to one side than to the other, to taper down much more sharply on the steep than on the gentle side, and to end somewhat like the point of a well-shaped quill, where the plumelets on one border of the shaft, being long, come bluntly round to the tip, while the shorter opposite ones prolong their curving margin more acutely out. In a horizontal section, therefore, of such a ridge, or the rudely horizontal one made by denuding waters, the curve of the outcrops, winding round the end from one side to the opposite, resembles much in its difference of rapidity of flexure on the two sides of the axis the curve of the dip itself, or the form of the wave as cut by a vertical section. A nice estimation of the form or style of this curve of outcrop in its two wings or branches is of essential importance to the field-geologist in tracing strata round the ends of anticlinals.

Where the dip on the steeper side of the axis is perpendicular or inverted, the abruptness of the turn in the outcrops at the axis is extreme—so rapid, indeed, as frequently to elude attention, the more especially as it very often happens in such cases, that the axis where this turn occurs below the crest of the hill is covered and concealed by a load of fallen fragments from above. It is not an uncommon occurrence in the Appalachians, where the strata on one side of the axis are much inverted, to find this saddle-line at the actual foot, or very low on the flank of the mountain, the whole of the upper rocks of the inverted set being in these cases crushed and cut away by denudation to the level of the adjoining valley.

b. *Erosion of Unsymmetrical Anticlinal Valleys.*

As in the instance of many anticlinal ridges, the axis or line of sharpest bend in many anticlinals denuded centrally into valleys is not a medial line, but lies near to one side. This condition prevails where one leg of the crust-wave is very steep compared with the other, or the whole flexure approaches to a fold with inversion. In all such cases where the strata of the steep-dipping side are perpendicular or overturned, the harder rocks of this border of the valley are greatly more eroded or cut down than the flatter-dipping ones of the other flank of the wave. So much is this the condition, indeed, in many of the larger Appalachian anticlinals, that while one of the monoclinal bounding ridges is a bold and massive mountain, the other, with the vertically-dipping beds, is often a low, narrow, and broken crest, or a mere line of ragged hills. Where such is the structure, the anticlinal valley is of course not a regular oval one, but it is straightest on the side of the steep dips; and the bed of the valley slopes, moreover, laterally towards that margin, from its being the side of easiest and deepest erosion. It also generally happens that the barrier on this side, even where it is not greatly broken down, is pierced by one or several gaps, while that of the opposite flank, massive and resisting, from the wide breasts of hard strata above the general valley-level in consequence of gentler dips, is entire, or without a notch. This state of matters exists in Milliken's Cove, an anticlinal valley of Will's Mountain, near Bedford.—(See Plate at p. 368, Vol. I.)

The annexed Sketch, accidentally omitted at page 774 of this volume, where it appropriately belongs, represents a naked surface of Umbral Red Sandstone, smoothed and striated by the passage of the boulder-drift. The locality is the Wilkesbarre and Easton turnpike road, nearly S. of the "Prospect Rock," on the S. side of the Wyoming Valley. It exhibits a condition of the abraded rocky floor of the drift, abundantly met with throughout this mountain-slope, and which is very instructive. The rocky surfaces dip from 30° to 45° towards the N.W., or into the Wyoming Valley, and the boulder-scratches point obliquely *up* the mountain-slope towards the S.W., as indicated in the cut, as if produced by fragmentary debris violently propelled against the sloping mountain-wall of the valley from the N., and deflected up and along the inclined plane out of the normal course of the unimpeded drift, which, except where thus obstructed and turned aside, observes a somewhat constant direction of S.S.E. The extensive prevalence throughout Northern Pennsylvania, and many other districts, of this *ascending* striation, effectually refutes, I conceive, the Glacial Theory of Drift, as far, at least, as it essays to explain the phenomena in North America. The striæ if caused by Glaciers should *descend* this mountain, which is as high as any within a wide space around it.

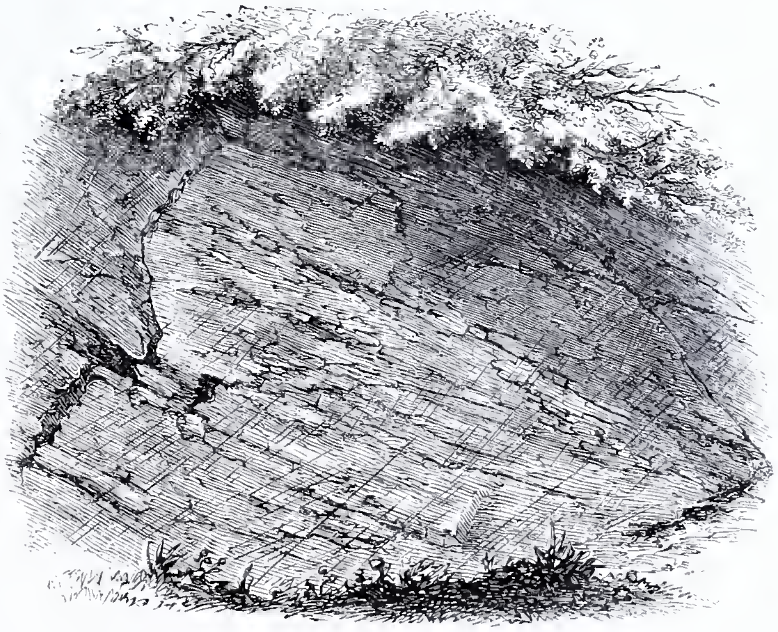


Fig. 766.—Diluvial Scratches deflected up and along the South Mountain barrier of the Wyoming Valley.

COAL-FIELDS OF THE UNITED STATES AND BRITISH PROVINCES.

Having presented in Books VIII. and IX. as accurate and complete a description of the Coal-fields of Pennsylvania as the information derived from the Geological Survey of the State admits, I propose, before quitting the subject of Coal, to furnish the reader with a general account of all the other great Coal-fields of the United States and the British Provinces, that the relative wealth and industrial capacity of our own favoured region may be correctly estimated in comparison with those of other districts of North America.

With a similar view of comparing or contrasting the resources in Fossil Fuel of Pennsylvania, and other parts of the United States, with those of other countries, I shall in a later division of this work introduce a somewhat analogous synoptic sketch of the chief Coal-Basins of Europe.

The reader will derive much assistance in the perusal of the following descriptions, from a frequent inspection of the Author's Geological Map of the United States, upon which he will find all the Coal-fields of the country carefully delineated, and their relations shown to the other formations.

CHAPTER I.

DESCRIPTION OF THE COAL-FIELDS OF THE PROVINCES OF BRITISH AMERICA.

The Coal-formation of that portion of the British Provinces which encircles the Gulf of St Lawrence occupies numerous detached areas. According to Professor J. W. Dawson, to whose interesting description of the geology of Nova Scotia and neighbouring provinces, entitled *Acadian Geology*, we are indebted for the chief facts embodied in the following statement, the formation consists of two groups of strata, the upper composed of greyish and reddish sandstones and shales, with beds of conglomerate, and thin beds of limestone and coal, the latter not economically important—in all more than 3000 feet thick ; the lower of dark-grey sandstones and shales, with occasional reddish and brown beds of bituminous limestone, and valuable seams of coal and ironstone, all possessing a thickness of more than 4000 feet.

These Coal-measures are underlaid by a lower carboniferous group called the Gypsiferous Formation : this is composed of reddish and grey sandstones and shales chiefly in the upper part, conglomerate in the lower part, and thick beds of limestone, with marine shells and beds of gypsum—the whole group being more than 6000 feet thick.

The Upper Coal-measures contain the usual vegetable remains of the coal-formation in its more terrestrial type, the fossils being ferns, calamites, coniferous wood, &c. The Lower Coal-measures exhibit, on the other hand, mingled with this characteristic vegetation, the remains of shell-fish, ganoid fishes, and of three species of reptiles. The Lower Carboniferous, or Gypsiferous formation, displays a blending of the fossil vegetation distinctive of the coal strata, with numerous shells, corals, and other relics of a decidedly marine type.

The general area occupied by the Carboniferous rocks of Nova Scotia is subdivided, by belts of the more ancient rocks, into eight separate coal-fields :—

1. The Cumberland coal district, bounded S. by the Cobequid Hills, and united on the N.W. with the great coal-field of New Brunswick.
2. The Hants and Colchester district, including a long strip S. of the Cobequids, and another in the valley of the Musquodoboit River.
3. The Pictou district, uniting W. with both of the preceding.
4. The Sydney district, bounded by metamorphic rocks.
5. A belt of carboniferous rocks, probably without Coal-measures, extending from the Straits of Canseau, West through the County of Guysborough.
6. The Richmond and South Inverness district.
7. The Inverness and Victoria district.
8. The Carboniferous district of Cape Breton County.

The reader will observe that the above is rather a classification of the geographical distribution of the carboniferous formation generally than of the upper half of it, the lower group of which alone contains any valuable coal-seams. Condensing the descriptions of the author of the *Acadian Geology*, I shall proceed to sketch the principal geological features of these carboniferous basins in the order here presented.

The Cumberland carboniferous area is a somewhat regular synclinal trough ; its S. side exhibits the lower carboniferous rocks stretching along the base of the Cobequids, and dipping N. towards the middle of the basin, and upon these rest the strata of the Lower or productive Coal group, observing the same dip. In the centre of the trough, the Upper or unproductive Coal-measures are seen to basin, inclining first to the N. at a gradually-subsiding angle, and then dipping S. The N. side of the basin displays the older Coal-measures, and the Lower Carboniferous group elevated in a bold anticlinal flexure, and finally dipping N. again into the broad coal-field of New Brunswick. One of the finest natural sections of the carboniferous series to be met with on the Continent is that which is presented by the truncated Western end of the Cumberland trough, in the cliffs facing Chiegnecto Bay. According to Sir William Logan,—the first to give a detailed description of this locality,—the part of the section called the South Joggins exposes nearly the N. side of the basin, showing the strata for about 10 miles under dips varying from 19° to 25°. It has been computed that the strata here exposed possess a vertical thickness of at least 14,000 feet, measuring from the top of the coal strata to the marine limestones of the lower carboniferous group ; and it is said that seventy separate seams of coal are to be counted, each with its roof-slate and under-clay.

The oldest beds of the Lower Carboniferous series, better studied near Amherst, consist of sandstones and marly clays, imbedding thick layers of marine fossiliferous limestone and gypsum. The limestone group is overlaid by a succession of sandstones and shales ; among these beds, some of which are reddish, occur layers of gypsum and sandy limestone, and some of the grey sandstones contain fragments of fossil trees in a coaly state.

The next group, estimated to be 3240 feet thick, contains nine thin seams of coal, in all only 10 inches thick; also several layers of hard bituminous black limestone, distinguished by small enamel-like shining scales of ganoid fishes; the grey sandstones are full of fossil plants. It is from some of these layers that the United States derive their chief supply of the well-known Nova Scotia grindstones, in such extensive use throughout the country.

Overlying the group last described occurs a group of strata 2082 feet thick, containing no coal-beds or bituminous limestone, and but little fossil vegetation, but abounding in reddish shales, and reddish and grey sandstones. The top of this group brings us to the base of the true Coal-measures, the estimated level of which is 7636 feet above that of the base of the lower carboniferous rocks. These Coal-measures have been divided by Professor Dawson into twenty-nine groups, estimated by him to possess an aggregate vertical thickness of 2819 feet. The total number of coal-seams of all dimensions in this division of the formation is forty-seven; of these there are forty of all sizes, from a thickness of half an inch to one of 14 inches. Of the remaining seven beds, the thinnest is 18 inches thick, and the thickest 5 feet; their aggregate gross bulk is 23½ feet, but only five of them are of a size adapted to economical mining: their aggregate thickness is about 20 feet, and the nett quantity of coal, rejecting the slaty partings, is probably about 16 feet.

Some of the groups or subdivisions of the productive Coal-measures are unusually interesting for their organic remains; not a few of them contain sandstone-casts of the stumps and stems of the tree-like plants of the coal period, standing athwart the strata, or in an upright attitude in relation to the originally horizontal bedding of the deposits. In one thick series of beds, Group XIII., there are not fewer than thirteen distinct forest surfaces marked by erect trees, or the under-clays of the coals, deemed to be the soils of as many swamps or jungles; and alternating with these are five layers, imbedding marine fossil shells, all implying as many periods of submersion beneath the sea. Some of the limestone-beds contain numerous remains of Modiola, a delicate shell; Cypris, a small crustacean animal; the scales of fishes; and even *coprolites*, the fossilised dung of probably some aquatic reptile. One group, No. XV., is especially interesting, as containing the bones of a curious reptile, the *Dendrerpeton Acadianum*, and the shell of a snail or land-shell, all found in the interior of an upright stump of a tree mixed with sand, decayed wood, and fragments of plants, which seem to have fallen into the tree after it became hollow. These curious evidences of an ancient dry-land, discovered in 1852 by Sir Charles Lyell and Professor Dawson, were incased in a bed of argillaceous sandstone 9 feet thick, imbedding numerous other erect plants.

Sir William Logan conceives that the physical conditions attending the production of the coal strata exposed at the Joggins, were "gradual and long-continued subsidence, with occasional elevatory movements going on in an extensive alluvial tract teeming with vegetable life, and receiving large supplies of fine detrital matter. On the one hand, subsidence tended to restore the original dominion of the water; on the other, elevation silted up, and vegetable and animal growth built up, successive surfaces with dry land. For a very long period these opposing forces were alternately victorious, without effecting any very decided or permanent conquest; and it is very probable that the locality of our section was, during this period, near the margin of the alluvial tract in question, where the various changes of the conflict were more sensibly felt and more easily recorded than nearer the open sea or farther inland."

The whole series of carboniferous strata exposed at the Joggins has been subdivided by Sir William Logan into the eight following groups :—

Nos. I. and II.—Grey and yellowish Sandstones and Conglomerates, and dark-red, chocolate-coloured, and grey argillaceous and sandy Shales. Remain of drifted and some erect coal-plants. Thickness 2267 feet. Professor Dawson regards these groups as identical with the upper coal-formation at Pictou.

No. III.—Grey and reddish Sandstones and Shales, carbonaceous shales, under-clays, and 22 seams of coal ; erect plants at two levels. Thickness, 2134 feet.

No. IV.—Grey and reddish Sandstones, and grey, reddish, and chocolate-coloured Shales—the grey most abundant. Carbonaceous shales, bituminous limestones, under-clays, and 45 seams of coal ; erect plants at 18 levels. *Modiola and fish-scales.* Thickness, 2539 feet.

No. V.—Reddish and grey Sandstones, and red and green Shales, red beds predominating. Calcareous concretions ; remains of carbonised plants. Thickness, 2082 feet.

No. VI.—Grey, drab, and reddish Sandstones two-thirds of the mass, grey and reddish Shales, under-clays and Bituminous Limestones ; 9 seams of coal, drifted plants abundant, and upright stems at one level. *Modiola and fish-scales.* Thickness, 3241 feet. (Groups Nos. III., IV., V., VI. are regarded by Sir William Logan as representing the productive Coal-measures of Pictou and Sydney, and some of the underlying sandstones.)

Nos. VII. and VIII.—Reddish and grey Sandstone, red Conglomerate, red and chocolate-coloured Shales, concretionary Limestone, and two beds of Gypsum ; plants. Thickness, 2308 feet.

These rocks, together with a thick underlying bed of limestone, represent the lower carboniferous or gypsiferous series of Winsor, Pictou, and other localities.

The whole coal-series, measuring, according to Sir William Logan, 14,570 feet vertical thickness, embraces 76 beds of coal, all, with two exceptions, resting on Stigmaria under-clays. There are, besides, 16 similar under-clays without coals above them ; erect plants occur at 22 horizons ; and there are 24 bituminous limestones, of which 17 are closely associated with seams of coal.

Clay ironstone, in balls and irregular bands, occurs among the strata at the Joggins, but not in sufficient abundance to be valuable. Grindstones, a useful product of these strata, are quarried on a large scale, 36,712 tons having been exported from Cumberland in 1851. Limestone and gypsum abound in the belt of country stretching from Minudie to Pugwash. Some of the beds of black bituminous limestone abound in scales and bones of fishes, and contain therefore a sufficient quantity of phosphate of lime to constitute the material a valuable manure.

COAL-FIELD OF NEW BRUNSWICK.

The extensive coal-field of New Brunswick is divided from that of Cumberland, just described, by an anticlinal belt of the older Carboniferous rocks, the axis of which passes through Chiegnecto Bay. North of this axis, the coal-rocks occupy a rather slender basin, bounded on its N. by a range of metamorphic strata culminating in Shepody Mountain, the synclinal centre of the trough crossing Shepody Bay. This basin heads towards the W.S.W., and expands between the Petitcodiac and the sea-coast at Northumberland Strait. North of the zone of older rocks of the Shepody Mountain spreads the main carboniferous area of the province, Northward as far as the Bay of Chaleurs, and Westward as far as Oromucto Lake. This is a broad triangular tract, 150 miles long from S. to N., and 100 miles wide from the sea-coast Westward. We may infer from its wide extent, and from the undulated outline of its Western border, that it is not one simple basin, but a succession of broad and shallow troughs, and intervening anticlinal flexures.

It would appear, from the researches of the Canadian geologists, that the basin of Shepody Bay is wanting in the middle and upper Coal-measures, its highest strata appertaining to the lower Coal-measures and the lower carboniferous series. Professor Dawson alleges that such, indeed, is the character of the entire coal area of New Brunswick, where lower carboniferous rocks, closely resembling those of Nova Scotia, seem to underlie a large portion of the basin, usually coloured in the geological maps as one continuous coal-field. The productive Coal-measures are evidently developed on a comparatively limited scale in this province; no actually valuable bed of coal has yet been brought to light, though beds of cannel coal, resembling bituminous shales, and thin seams of ordinary coal, do occur. The most important, certainly the most curious, mass of fuel in this district is the bed or vein of the Albert Mine near Hillsborough. This substance, the chemical nature and geological relations of which have occasioned much discussion in connection with a legal definition, does not wear the aspect of an ordinary coal, but is a much more fusible substance of a splendent resinous lustre, and a perfect conchoidal fracture. It is destitute of the lamination of coal, but has the structure of a pasty substance, which has been stirred while in a plastic state before consolidation. Its powder and streak are black, and it is very brittle; its specific gravity, about 1.10, is less than that of the lightest varieties of common coal; it emits a bituminous odour, puffs when exposed to flame, evolves a copious volume of gas, and melts in a close vessel, but not in the open air. In these properties it resembles jet or pitch coal. As this substance contains the unusual proportion of 57 per cent of volatile inflammable matter, it is admirably adapted for the economical production of illuminating gas, for which it has been successfully employed.

As exposed in and near the Albert Mine, this material would seem not so much to constitute a true bed or layer conformably imbedded between the strata, as to fill an irregular fissure or fissures connected with a dislocation of the strata. Professor Dawson supposes it to have been a bed of true coal disturbed and contorted while soft, and with the enclosing rock bent into a sharp arch, the arch to have been dislocated and denuded in its upper part, making the strata on the one side of the coal to abut against it, and to squeeze it while in a plastic state into the adjoining fissures: if so, the carbonaceous mass must eventually resolve itself in the progress of mining into a regular coal-seam, with conforming floor and roof. The question here arises, will it then possess the abnormal chemical and physical properties which it at present exhibits? It is difficult to conceive how these can have arisen from mere mechanical pressure, however energetic, upon a bed of ordinary coal, even though softened and rendered plastic by heat; and this objection becomes stronger when we reflect that hitherto no instances of a change in the nature of a coal have ever been found to accompany the faults and squeezes so common in nearly all coal-fields. It is barely possible that this bed of carbonaceous matter, originally very hydrogenous, and easily softened or rendered plastic by heat under an excessive squeeze exerted at a line of flexure or fault, may have extruded its more fused or liquid portion from out of the more solid part of the bed into the vacant fissure, very much after the manner in which the fluid oils separate from the solid fatty bodies with which they are associated in animal structures.

But this modified form of the hypothesis lacks support upon the ground already mentioned, that the history of mining has hitherto failed to exhibit any instances of such exudation of the bituminous portions of coal-seams, or indeed any change of chemical composition from mere compression. While, therefore, we cannot doubt that the material exposed within and around the Albert Mine was in a pasty state at the time it assumed its present position between the rocks, we can hardly assume it to be either a metamorphosed condition of true coal, or a derivative part of a genuine coal-seam, but itself an original product or formation ; in other words, a genuine coal elaborated by chemical action from vegetable matter, and thrown while soft, or after it had been rendered plastic, into its present posture by forcible disturbance of the strata. To account for its peculiarities of composition, we must look rather to conditions under which the deposit was originally collected and elaborated, than to any subsequent changes attributable to geological forces. Regarded from a geological point of view, this much-discussed hydro-carbon must rank therefore as a genuine coal, using this word to designate not a specific mineral or chemical compound, but a genus of substances having a common or similar geological history, possessing carbon for their base or principal constituent, traceable to a similar origin in vegetable matter, and applicable to similar uses in the arts.

CARBONIFEROUS DISTRICT OF COLCHESTER AND HANTS.

There is an extensive irregular basin of carboniferous rocks on the S. side of the Cobequid Hills, which possesses as large an area as the basin of Cumberland; its general Southern boundary is the Northern base of the Horton and Ardoise Hills, against the ancient rocks of which the lower carboniferous beds lean at a high angle. This tract appears to have the structure of an undulating trough, the main synclinal axis of which ranges E. and W. through the basin of Minas, passing South of the Pictou coal-field ; it contains but a very limited tract of productive Coal-measures, by far the largest portion of the district consisting of only the lower carboniferous series, which are to be found here as well exposed, and under as full development, as the Coal-measures are at the Joggins.

These lower carboniferous rocks consist for the most part of grey sandstones and dark shales, some of the former containing well-preserved coal-plants. At Horton Bluff there occur also many layers of coarse limestone among grey and red sandstones and marls. The enamelled scales and pointed conical teeth of *Palæoniscus* and other ganoid fishes are abundant in some of the shales in this locality, while other beds contain the trunks, branches, and leaves of *Lepidodendron* and other coal-plants. The Horton shales are regarded as the geological equivalents of the strata of Hillborough, but they have not disclosed any seam of the remarkable bituminous matter exposed at the Albert Mine. One stratum exhibits stems of *Lepidodendron* rooted in an erect position across the strata ; older relics of a fossil forest are nowhere known. In the same group of strata it is not uncommon to find the *Coprolites*, or fossilised excrements of fishes ; and even the footprints of a small reptile have been noticed. No seam of coal has been met with in these lower strata. Many of the strata of this basin are of a strictly marine type, being flaggy limestones, imbedding numerous fossil-shells belonging to species of *Productus, Spirifer*, and *Terebratula*, which are indicative of a marine origin, and characteristic of the early carboniferous ages. Associated with the marls and limestones of this group is much white crystalline gypsum, which makes a conspicuous display from its whiteness. This valuable material is developed on a large scale at Windsor, where there are great quarries of it. A very striking natural exposure of the gypsum occurs on the St Croix River, where the material stands forward in glittering whiteness from the face of a long range of cliffs.

The Coal-measures of this broad basin occur chiefly in the neighbourhood of the Folly River, across which they stretch from near Cape Chiegnecto to the upper part of the Salmon River. These coal-rocks repose on the oldest grits of the lower carboniferous series, without being underlaid by any intervening marine limestones. The group consists of grey sandstones and dark shales, imbedding a few thin layers of coal. On the Salmon River they contain a bed of coal about 2 feet thick, accompanied by shale imbedding characteristic coal-fossils.

The carboniferous district of Colchester divides into three sub-basins E. of the Shubenacadie, by the intrusion of narrow belts of metamorphic strata. The most Northern follows the valley of Salmon River into the Pictou district; the other two sub-basins do not contain the coal-formation in their extension E.

It is stated that nearly 80,000 tons of gypsum were quarried and exported in 1851 from Windsor, Shubenacadie, and other localities of the gypsum-bearing strata accessible to shipping.

Iron ore, but not in quantities sufficient for smelting operations, is to be met with near the entrance to the Shubenacadie, among the lower carboniferous strata.

Coal, but in thin seams, none of them exceeding 18 inches in diameter, occurs, according to Professor Dawson, at Salmon River, North River, Chiganois River, De Bert River, Folly River, and Great Village River, and appears at intervals as far W. as Cape Chiegnecto.

CARBONIFEROUS DISTRICT OF PICTOU.

The carboniferous basin of Pictou, bounded on the S. by the older schistose rocks of the N. slopes of the Blue Mountain and the Cobequid Mountain, contains a full development of both the lower carboniferous series and the productive Coal-measures. The lower carboniferous rocks half enclose it in a crescent-shaped belt, extending from the coast a little West of Arisaig, S.W. and N.W. to Tatmagouche Bay. This group of strata consists in this basin of conglomerates, with interstratified beds of amygdaloidal trap-rocks as a bottom group, and upon these a succession of reddish and grey sandstones and shales—a thick limestone, with characteristic fossils, forming the upper part of the series; while associated with the limestone are layers of marl and gypsum.

The Coal-measures consist of the very same materials as they do at the Joggins, except that instead of containing a multitude of thin seams of coal and bituminous shale, they here enclose only a few beds of comparatively great thickness. They are well exposed on the East River of Pictou, especially around the Albion Mines. At this locality the strata, according to Professor Dawson, have a thickness of about 800 feet, and are chiefly black shales, with *Cypris* and ferns, and other fossil plants. The number of coal-seams is five or six, the two largest measuring respectively 37½ and 22 feet: the thicker of these, called the Main Seam, is traceable by its outcrop for several miles, and has already been extensively wrought. A serious fault, or line of disturbance, cuts off the Coal-measures towards the N., or on the coast, by causing a downthrow of a thick bed of conglomerate which overlies the coal. This conglomerate, unlike that of the lower carboniferous group, is composed of large pebbles cemented by calcareous matter: it is imagined by Professor Dawson to represent an ancient gravelled beach, contemporaneous with the Albion Coal-measures, and isolating them from the wider area of coal strata on the N. towards Pictou. He "conceives that the Albion coal was formed in a depressed space separated by a shingle bar from the more exposed flats without," accounting thus "for the great thickness of the deposits of coal and carbonaceous shale, the absence of sandstones, and the peculiar textures and qualities of the coal, as well as the association with it of remains of fish and *Cypris*, since modern analogies show that such an enclosed space might be alternately a swamp and lagoon, without any marked change in the nature of the mechanical deposits."

It would appear that the synclinal axis of the Pictou coal-field cannot be far from the town of that name, since, according to Professor Dawson, "the strata to the N. and W. of Pictou Harbour dip gently towards the S.E." Near the town of Pictou a bed of sandstone is seen with erect stems of *Calamites* rooted in the spots in which they grew; relics of the other ordinary coal-plants in their usual condition abound.

The N. side of the coal-field between Pictou and Cape John is traversed by an anticlinal axis ranging from near the mouth of Carribou River across French River at Tatmagouche; beyond this axis there would seem to be another lying still farther N., producing S. dips in the lower carboniferous strata forming the N. side of the Cumberland coal-field. It would thus appear that the Pictou and Cumberland basins occupy separate troughs of the strata, divided from each other by the Carribou anticlinal.

The Main Pictou coal-seam is composed as follows:—

Roof, slate fragments, 3 inches; Coal, shaly, 6½ inches; Coal, laminated, thin layers of mineral charcoal, 2 feet; Coal, cubical, 3 feet 2 inches; Carbonaceous Shale and Ironstone; Remains of large Fishes and Coprolites, 4½ inches; Coal, laminated and cubical, 9 feet 3 inches; Ironstone and Carbonaceous Shale, with Lepidodendron, Ulodendron, Sigillaria, &c., 8 inches; Coal, laminated, a line of ironstone balls, 1 foot 2 inches; Coal, laminated and cubical, 6 feet 7 inches; Ironstone and Pyrites, 3 inches; Coal, laminated and cubical, 10 feet 3 inches; Coal, coarse, with layers of bituminous shale and pyrites, 1 foot; Coal, laminated, with a fossil trunk in pyrites, 2 feet 1 inch; Coal, laminated and cubical, 2 feet 3 inches; Under-clay, 10 inches. Thickness perpendicular to horizon, 40 feet; vertical thickness, 38 feet.

The actual thickness of good coal is about 24 feet. The chemical constitution and physical properties of this coal will be found in the General Table.

Another coal-bed of the Pictou basin—the "Deep Seam," so called—lies about 150 feet below the main seam; it contains about 12 feet of good coal in three benches, the best of which is said to be superior to any part of the main seam, but owing to subdividing layers of shale, it cannot be mined as economically as the large bed. It yields much illuminating gas, and an excellent vesicular coke, and produces but a moderate amount of ashes. These ashes, Professor Dawson states, "are for the most part of a reddish colour, whereas those of the main seam are invariably white or light grey;"—a reverse relationship, it will be remarked, to that which obtains in the anthracite basins of Pennsylvania, where whitish ashes characterise, with but one or two exceptions, all the lower coal-seams, while reddish ashes everywhere prevail in the upper.

Other good coal-seams occur in the Albion Coal-measures; "one of them, similar in quality to the main seam, but containing more ashes, is 6 feet thick; another, yielding 8 per cent of ashes, a good vesicular coke, and 56.6 per cent of excellent illuminating gas, lies 450 feet below the main seam; it is said to be only 14 inches thick. There are several small seams of coal at New Glasgow, Merigomish, Middle River, South Pictou, Carribou, and elsewhere, but they are too thin to be profitably mined; those of the Albion Measures, already referred to, are the only thick seams at present known within the Pictou basin.

Clay iron-stone is to be met with in the Albion Coal-measures in sufficient abundance, and of fit quality, it is said, to warrant the erection of smelting-furnaces.

A grey freestone, now in some demand in the Atlantic cities of the United States for architectural uses, is quarried on a large scale at the head of Pictou Harbour; it has the requisites of durability and an attractive colour.

Fossils.—A curious fossil was discovered by Professor Dawson in 1850, in a seam of coaly ironstone in the Albion Coal-measures; it is the upper part of a skull, supposed by Professor Owen, to whom it was submitted, to have belonged to a gigantic frog-like reptile or *Batrachian*, of a type not previously found in rocks as ancient as the Coal-measures. The specimen is 7 inches broad and 5 long, and along its semicircular margin it is provided with strong, conical, finely striated, and slightly-curved teeth. It is one of sundry curious relics of frog-like reptilian life already recovered from the American Carboniferous formations.

CARBONIFEROUS DISTRICT OF SYDNEY COUNTY.

A wide basin of the carboniferous strata occupies a triangular area in Sydney County, Nova Scotia, extending W. from the Gut of Canseau, and the S.W. shores of St George's Bay, to the stream called the Ohio River. It is bounded on the S. by the older crystalline rocks of the Cape Porcupine range of hills, and on the W. by the similar formations of the Antigonish Mountains, terminating on the N. by the Cape St George; this would appear to be a broad synclinal trough, deepening and widening rather rapidly N.E. towards St George's Bay. All its marginal tracts adjoining the bounding hills are occupied by the lower carboniferous series constituted of the usual conglomerate, and sandstone, limestones, and gypsiferous beds of the formation; the latter materials existing in great abundance. The gypsum alone is stated by Professor Dawson to be at least 200 feet thick, and to form at one place a beautiful cliff fronting the sea.

The Coal-measures occur in the central parts of the basin, inland from Pomket and Tracadie, but only thin seams of coal have hitherto been met with. It does not appear probable that any valuable seams of coal occur.

CARBONIFEROUS DISTRICT OF GUYSBOROUGH.

South of the belt of metamorphic and crystalline rocks, and between it and a similar range, extending W. from Cape Canseau, there lies another trough of Carboniferous strata, encompassing the head of Chedebucto Bay, and stretching thence due West past Glen Elbe, and along the upper valley of St Mary's River. This basin appears to contain no Coal-measures, being too narrow and shallow for their reception; but it embraces some valuable beds of limestone both N. and S. of the town of Guysborough.

CARBONIFEROUS DISTRICT OF RICHMOND AND SOUTH INVERNESS.

East of the Gut of Canseau and St George's Bay, the carboniferous strata re-occur in the island of Cape Breton, the North-dipping lower members of the formation of Tracadie coalescing with the South-dipping corresponding rocks of the N. side of Chedebucto Bay, by the sinking under of the igneous axis of Cape Porcupine; an anticlinal flexure probably traverses the district from Cape Porcupine N.E. towards the head of Bras d'Or Lake. Apparently none but lower carboniferous rocks occur N. of this anticlinal in South Inverness; but these lower strata there developed are interesting for their abundance of gypsum. The Richmond portion of the tract, which is a prolongation of the Guysborough basin, does contain a patch of Coal-measures; but no coal-seam has yet been mined in it. There is a thick bed of mixed coal and shale immediately on the coast in Carribou Cove; it measures 11 feet 8 inches, stands vertically, or indeed a little overturned, dipping 80° W., 57° S. The coal is crumbly and soft, and is evidently not in a workable condition. Coal likewise appears at Little River, a small tributary of Carribou Cove.

The lower carboniferous series is admirably displayed in the neighbourhood of Plaister Cove, on the Gut of Canseau. Professor Dawson thus describes them :—

Group 1.—Thick beds of grey conglomerate, under a nearly vertical dip, form the base of the carboniferous series. These appear at M^c^Millan's Point, between which and Plaister Cove occurs

Group 2.—Composed of black and grey shales alternating with hard sandstones, altered by heat, and intersected by white veins of calc-spars. Overlying these is

Group 3.—This consists of a bed of dark sub-crystalline limestone, 30 feet thick, also traversed by many thin cracks, filled by calcareous spar; and upon the limestone are layers of greenish marl and gypsum, somewhat contorted. Next succeeds

Group 4.—Composed of greenish marl, with grains of red foliated and fibrous white gypsum, and a few slender ones of calc-spar; the greenish marl contains sulphuret of iron. Above the marl reposes

Group 5.—A bed of gypsum, estimated to be 50 yards thick. This great mass of sulphate of lime forms a cliff about 80 feet high, shaped grotesquely by the action of the weather. Two-thirds of the bed consist of crystalline anhydrite, the remaining one-third of common gypsum forming a base, imbedding the anhydrite in minute crystals. The mass is perforated perpendicularly by slender tubular holes or channels, called "Plaister Pits," caused by the solvent action of surface water trickling down the steeply-inclined joints.

Group 6 embraces a few layers of limestone, resting at a steep angle on the gypsum. One of these is a curious mixture of grey limestone and gypsum, the result, apparently, of the cementing together of fragments from the two rocks.

Group 7 is a thick bed of marl like that underlying the gypsum; it is partly homogeneous, partly brecciated, and some layers of it are highly gypseous.

Group 8, the highest in the series, is a thick succession of dark calcareous shales, overlaid by a thick mass of hard grey and brownish sandstones and shales.

The dark shales are overlaid by true Coal-measures, the same which at Little River and Carribou Cove imbed regular seams of coal.

The chemical composition of the coals of Carribou Cove will be found in the General Table.

CARBONIFEROUS DISTRICT OF NORTHERN INVERNESS AND VICTORIA.

A long and irregular tract of carboniferous rocks extends the whole way from the W. shore of St George's Bay to Cheticamp. Between Plaister Cove and Port Hood it is but a narrow strip of the lower members of the series facing the sea. Between Port Hood and Margarie the Carboniferous area widens, spreading from the sea Eastward to the waters of Bras d'Or and St Ann's Bay, but broken by the intrusion of spurs and ridges of the igneous rocks ; and between Margarie and Cheticamp it is again only a narrow strip restricted to the coast. The chief part of this long tract embraces the lower carboniferous series, under its usual Nova Scotian type : the lower beds consisting of conglomerates and limestone, in some localities much altered by igneous action. Associated with the carboniferous limestone is much gypsum; these valuable materials are largely developed to the N.E. of Port Hood, and thence N. to the Mabou River, where the limestone may be identified by characteristic fossils. Like some parts of the Carboniferous or Umbral limestone of the United States, a portion of it is oolitic. According to Professor Dawson, there is an enormous bed of gypsum near the mouth of Mabou River. These rocks are also largely developed at Ainslie Lake, and on Margarie River, its outlet. According to descriptions of Mr Brown, in the *Proceedings of the Geological Society,* the lower carboniferous rocks of the East coast of Cape Breton have a total thickness of about 1000 feet, which is much less than their average thickness.

The Upper Carboniferous series or Coal-measures occur on only two or three limited patches within this large area : one locality is Port Hood, where these strata much resemble those of the Joggins. The formation consists of grey sandstones, grey and brown shales, black and calcareous shales, and thin beds of coal, with the usual fossil vegetation. Professor Dawson speaks of superb examples of stumps of Sigillaria, with roots and rootlets attached, imbedded where they grew, and exposed by denudation over a broad horizontal surface, permitting a full view of the subdivisions of the roots, and their junctions with the stems. Some of these stumps are 2½ feet through, and show the Stigmaria roots diverging from them in four directions, at right angles to each other, each main root forking into two, and each branch-root also into two, and so on. Other beds of the group contain characteristic marine fossils, *Modiolæ, Cypris, fish-scales, coprolites,* &c.

Another locality of the Coal-measures is Margarie ; but here the strata are very limited. It would appear from the seaward dip of all the strata, that the main coal-field lies to the N.W., beneath the Northern parts of Northumberland Straits, the small patches of the formation at Port Hood and Margarie being merely marginal portions of it which have escaped submergence. All the coal-beds are stated to be small, the largest seen by Professor Dawson, *not exceeding one foot in thickness.*

CARBONIFEROUS DISTRICT OF CAPE BRETON COUNTY.

The only remaining tract of carboniferous rocks, in this part of the British Provinces, is that which constitutes an irregular triangular area in the Northern and central parts of Cape Breton County ; it may be called the Sydney Basin, as that town lies somewhat centrally within it. It is bounded N. by the sea, W. by the waters of the Great Bras d'Or, Little Bras d'Or, and Bras d'Or Lake, and Southward by a belt of igneous and metamorphic rocks, extending Eastward from the last-named sheet, to the open Atlantic at Cape Breton. This irregular triangular area, which includes Boulardarie Island, is penetrated and made irregular by the tidal estuaries of Bras d'Or, Sydney Harbour, and Miré River, and by a band of crystalline rocks in the Sunacadie Hills. The geology of the district has been well explored by R. Brown, Esq. of Sydney, from whose written description the following condensed account is mainly derived.

It embraces both the Lower Carboniferous series and the productive Coal-measures: its general structure is that of a wide undulated trough, spreading and deepening in a N.E. direction from Miré River towards the sea: it is apparently traversed by several anticlinal flexures ranging N.E. and S.W., by virtue of which the strata are disposed into as many intermediate subbasins, the largest of which occupies the peninsula between Sydney Harbour and Miré River, Boulardarie Island apparently constituting a lesser one.

The Lower Carboniferous group consists of very nearly the same materials as it possesses elsewhere in Cape Breton and Nova Scotia—that is to say, conglomerate, sandstone, shale, limestone, and gypsum, disposed in their usual order. These rocks lean in many places on the steeply-dipping edges of the older slates. The limestones abound, in some localities, in well-preserved fossils; and gypsum is developed on a large scale, though it is nowhere extensively quarried.

The Coal-measures occupy all the Northern or seaward front of the county, extending, in fact, from Great Bras d'Or across the N. end of Boulardarie Island, the Northern half of the peninsula between Little Bras d'Or and Sydney Harbour, and all the Northern part of the wider peninsula between the latter and Miré River. Mr Brown conceives "that this great area of Coal-measures is probably the segment only of an immense basin extending towards the coast of Newfoundland—a supposition which is confirmed by the existence of Coal-measures at Neal's Harbour, 30 miles N. of Cape Dauphin." The same authority states that "the productive coal strata cover an area of 250 square miles, and he thinks they possess a thickness of 10,000 feet. One continuous section, on the N. shore of Boulardarie Island, exposes a thickness of 5400 feet; and other sections, nearer the middle of the field, display between 1000 and 2000 feet more, referable to a higher place in the series."

A natural section, on the N.W. side of Sydney Harbour, exhibits, in 1860 feet of strata, thirty-four seams of coal, and forty-one Stigmaria under-clays; the coal-beds measuring, in the aggregate, 37 feet. There are eighteen distinct courses of erect trees, chiefly Sigillaria, and many of these exhibit their roots of Stigmaria very plainly. These were among the first instances anywhere cited of the true nature and mode of growth of Stigmaria.

In the fifth volume of the *Geological Journal*, Mr Brown describes a specimen of *Sigillaria alternans* with Stigmaria roots attached, subdividing and having conical tap-roots penetrating downwards into a thin bed of shale overlying a coal-seam. This coal-bed, "like the main seam at the Joggins, supported, when it was a bed of soft peat, a forest of *Sigillaria and Lepidodendron*, many of which still remain erect in the overlying shale, with all their roots and long spreading rootlets attached." In one instance the roots dip gradually downwards until they come in contact with coal at about 18 inches from the centre of the tree, and then spread out over its surface. The horizontal roots branch off in a remarkable manner, the base being first divided into four equal parts by deep channels running from near the centre. An inch or two farther on, each of these quarters is divided into two roots, which, as they recede from the centre, bifurcate twice within a distance of 18 inches from the centre of the stump. There are four large tap-roots in each quarter of the stump, and about 5 inches beyond these a set of smaller tap-roots striking perpendicularly downwards from the horizontal roots, making forty-eight in all—sixteen in the inner, and thirty-two in the outer set ; and, what is a still more remarkable feature in this singular fossil, there are exactly thirty-two double rows of leaf-scars on the circumference of the trunk. This curious correspondence in the numbers of the roots and vertical rows of leaf-scars surely cannot be accidental?

Besides erect trees and other forms of the Carboniferous vegetation, the Sidney Coal-measures contain many layers of shale imbedding *Modiola*, *Cypris*, *Spirorbis*, *Fish-scales*, and other aquatic animal-remains.

Only four out of the 34 coal-seams of the Sydney Harbour section are of workable dimensions ; one, the Indian Cove Seam, is 4 feet 8 inches thick ; the Main Seam, 450 feet above the Indian Cove bed, is 6 feet 9 inches thick ; the Lloyd's Cove Seam, 730 feet higher than the Main Seam, is 5 feet thick ; and the Cranberry Head, or top seam, 280 feet higher than Lloyd's Cove Seam, is 3 feet 8 inches thick. For the chemical and physical characters of the Sydney Main Seam, the reader is referred to the General Table.

Valuable beds of coal have been opened on Boulardarie Island, but these are not at present wrought. Other beds, important for their size, are seen at Bridgeport ; one of these, about 9 feet thick, appears to be an excellent coal.

CHAPTER II.

GENERAL DESCRIPTION OF THE GREAT APPALACHIAN COAL-FIELD.

LIMITS AND DIMENSIONS.

The longest, and in area the most extensive, of the five great coal-fields of the United States is that which I have designated the Great Appalachian Basin. Extending as it does in a S.W. direction, from Northern Pennsylvania to Middle Alabama, parallel with the Appalachian Mountains, many of whose great ridges rise within its borders, and insulate valleys of the coal-bearing strata, it seems fairly entitled to the name here conferred on it. This great coal-field, almost the largest expanse of continuous Coal-measures in the world, possesses a length of about 875 miles, and a maximum breadth, between its E. outcrop in Southern Pennsylvania, and its W. in Northern Ohio, of about 180 miles ; while it covers about 56,000 square miles of the earth's surface. Its general outline is that of a short rough club, the slender part, the table-land of the Cumberland Mountain in Tennessee, representing the handle.

The S.E. border of the coal-field may be defined as commencing in Lycoming County, Pennsylvania, in the summit of the Alleghany Mountain, and as pursuing a general S.W. course, coincident with the N.W. slope of that ridge or table-land, obliquely across the State to the head-waters of the Youghiogheny in Maryland. Near the S. boundary of Pennsylvania it offsets Westward, and, continuing its course S.W. through Virginia, ranges on coincident with the N.W. slope of the Briery Mountain, Laurel Hill, Rich Mountain, Big Sewell, Mountain, Great Flat-Top Mountain, and Cumberland Mountain, to the border of Tennessee. From the Northern line of Tennessee, it extends across that State to Alabama, coinciding nearly with the South-eastern escarpment of the Cumberland Mountain, and its Eastern spur the Lookout Mountain. From the Tennessee River, near the Northern line of Alabama, to the termination of the coal-field E. of Tuscaloosa, the boundary pursues the same S.W. direction, following the summits of the ridges immediately West of the Coosa River.

The N. and W. border of the coal-field is traceable from Lycoming County westward through Northern Pennsylvania, in a winding and very broken line, through Tioga, Potter, M^cKean, Warren, Crawford, and Mercer counties to the State-line of Ohio, crossing which, it takes a more Southerly trend to the Ohio River, through Turnbull, Portage, Summit, Wayne, Holmes, Coshocton, Licking, Fairfield, Hocking, Vinton, Jackson, and Sciota counties. From the Ohio River, the line ranges across Kentucky in a S.W. direction, passing through Greenup, Carter, and Morgan counties to the head-waters of the Tygert River, and thence by the W. boundary of Morgan and Laurel counties, and down the Rockcastle River to the Big Narrows of that stream, beyond which it runs to the Cumberland River, in Pulaski County, near the Shoals. Its course thence is winding through Wayne County by Slone's Hill and the Wallace Mountain, where it enters Tennessee; in which State it winds with still more tortuous bendings through the spurs of the Cumberland Mountain in Fentress, Overton, Putnam, White, Van-Buren, Grundy, and Franklin counties, and enters Alabama. In this latter State, the margin of the coal-field, still conforming to the summit of the W. escarpment of the Cumberland Mountain plateau, ranges irregularly through Jackson, Madison, Morgan, Bench, Hancock, Marion, Fayette, and Tuscaloosa counties, to the termination of the coal-field N. of the town of Tuscaloosa.

This extensive coal-field is, in its general structure, a broad comparatively flat synclinal trough, undulated in many wide low flexures, or gentle anticlinal and synclinal waves, of great length and continuity. These flexures are both straight and curved in the lineation of their axes. Like those of the more folded portions of the Appalachian chain, they are parallel with the general trend of the coal-field and with each other, and display a prevailing declension in the steepness of their slopes, as they succeed each other from S.E. to N.W. They are most numerous and conspicuous in Pennsylvania and Virginia. It is to the influence of a powerful and deep erosion upon a terminal group of these undulations that the coal-field is subdivided, in Northern Pennsylvania, into six long slender synclinal mountain-spurs or fingers, extending N.E. between deep valleys of older strata. From the superior hardness of the sandstones supporting the Coal-measures, compared with the subjacent clayey rocks, the margin of the coal group is very generally the edge of a mountain table-land, so that the whole field may be viewed as carved in relief out of the general plane of the country, by excavation of the circumjacent softer strata.

Many extensive rivers intersect and drain the basin. The Ohio River, and its main upper tributary the Alleghany, water it longitudinally from near the S. border of New York to the N. frontier of Kentucky, and it is drained transversely in the N.E. by the West Branch of the Susquehanna, centrally by the Great Kenawha and Big Sandy rivers, and near its S.W. extremity by the Tennessee River. The deep valleys of these and other great streams serve as so many trenches across the basin to promote in a most fortunate manner a wide intercourse and commerce between the interior of the table-land and the external country; and the general elevation of the basin, especially of its marginal portions above the bordering valleys, and these intersecting river-channels, places an enormous body of the mineral wealth of the coal-field in positions of unusual fitness for mining, and for transportation to the external markets.

COMPOSITION OF THE COAL-MEASURES.

The full and minute description of the Coal-Measures of Pennsylvania presented in this work will suffice to convey a sufficiently clear and accurate knowledge of the type which they wear in the N.E. portion of the basin, and may serve as a standard for comparison with the other parts. They consist of grey and yellowish quartzose grits, and sandstones, argillaceous sandstones, sandy and micaceous slates and shales, argillaceous shales and fire-clays, calcareous shales or marls, argillaceous and pure calcareous limestones, occasionally layers of chert, thin layers of argillaceous iron-ore, in continuous plates and in detached balls, and seams of coaly slate, and of more or less pure coal. These constituents are not interstratified in the same proportions throughout all parts of the deposit, nor do the same subdivisions of the formation retain a very constant character throughout wide geographical limits. As a general rule, the coal strata of this great basin graduate from a littoral to a more marine type as they spread toward the W. or N.W.; that is to say, the sandstones become fewer, thinner, and less pebbly, finer-grained, and more argillaceous; the shales and slates less sandy and more calcareous, the limestones purer, thicker, and more abundant; and the organic remains—the most significant of all—less exclusively terrestrial, or more aquatic. This gradual modification of type obtains as strikingly in the middle or Virginia and Kentucky division of the coal-field, as in the N.E. or Pennsylvania portion; but whether it is noticeable to the same degree in the S.W. or Tennessee and Alabama subdivision, has not been ascertained, owing chiefly to the narrower dimensions of the basin in that quarter. A far more rapid change in the materials may be observed in crossing the coal-field in an E. and W. direction than in passing an equal distance in the direction of its length—a fact true, indeed, of nearly all the Appalachian formations. We shall see hereafter, when examining the composition of the Western Kentucky or Illinois coal-field, that the same law of a more marine type towards the W. is as discernible in crossing from the one great basin to the other, as it is in traversing the Appalachian coal-field alone. Perhaps in this circumstance we may discern an indication that the two great basins were originally connected and continuous, and that their insulation has arisen simply from an extensive denudation of all the upper strata at the wide anticlinal zone, which extends from the limestone district of Cincinnati to the limestone tract of Lexington and Nashville. A similar and even more striking Westerly increase of the marine type, so far as this is indicated by an augmented proportion of limestones and marine organic remains, is discernible when we compare the composition of the Illinois coal-field E. of the Mississippi River, with that of the Missouri basin W. of it. Similarity of mineral constitution, but especially this fact of its gradation, when taken together with other geological considerations, almost compels us to believe that these two coal-fields were once conjoined, and that their separation was produced by a wave-like disturbance of the crust, and a deep and wide erosion of the carboniferous rocks in the valley of the Upper Mississippi.

It has been shown that the bituminous Coal-measures of Pennsylvania are divisible into five groups; a lower group, consisting of the Seral conglomerate, and two or three imbedded coal-seams;

a productive group of older Coal-measures ; an unproductive mass of coal-shales ; a second productive group of newer Coal-measures ; and a second unproductive mass of shales, which terminate the formation. These groups are discernible in Western Virginia as well as in Western Pennsylvania ; but it is not at present known how much farther in the S.W. direction they maintain themselves. The lower or conglomeritic group seems indeed to encompass and underlie the entire coal-field; but the two upper ones—the upper productive Coal-measures, and the still higher upper unproductive or Barren shales—are restricted to the widest and deepest part of the general basin, not extending, apparently, beyond the Guyandotte River. It is probable, therefore, that the coal-beds of the Cumberland Mountain, in Kentucky and Tennessee, belong chiefly to the lower Coal-measures, and to the Conglomerate series underneath them. For a general representation of the Coal-measures of Western Pennsylvania, the reader is referred to the column on page 475, and for a view of those of Western Virginia to the figure (767).

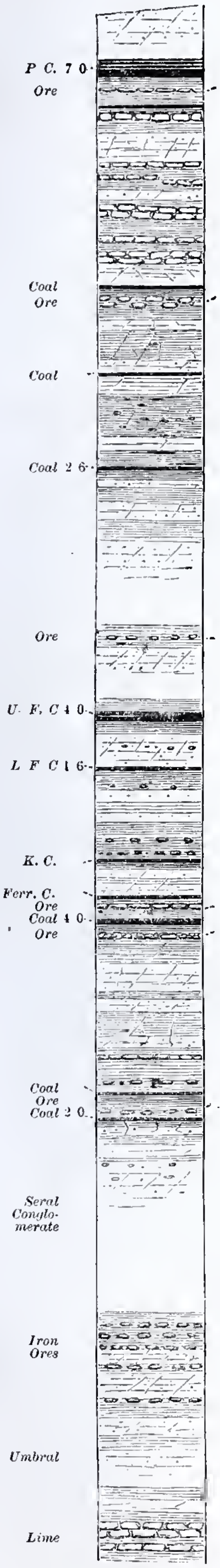


FIG. 767. — Section of Strata N. W. side Laurel Hill, Cheat River, Virginia. — 1 *inch* = 200 *feet.*

COAL-BEDS.

When treating of the anthracite basins, in our general descriptions of the Coal-measures of Pennsylvania, it was shown that the deepest of these, the Southern or Pottsville Field, embraced not less than fifty coal-seams, including beds of all dimensions, of which about *twenty-five* are of workable size. In the account of the bituminous coal strata of Western Pennsylvania, some nine or ten workable beds are shown to exist in that district, in a thickness of less than 2100 feet of strata ; the same number can be identified in North-western Virginia, and probably in South-eastern Ohio, where the strata crop out on the opposite side of the Great Basin. A less and less number will be found to prevail as we trace the coal-field S.W. to the intersection of the Tennessee River. It will appear hereafter that the Coal-measures of Western Kentucky, belonging to the S.E. end of the Great Illinois basin, contain about *seventeen* workable coal-beds in a thickness of more than 3400 feet of Coal-measures ; and it will also be seen that the still more W. coal-field of Missouri and Iowa exhibits, on the Missouri River, where the formation is obviously in full development, not more than *seven* or *eight* coal-seams of a size fit for mining, and that these are included in about 700 feet of strata.

This striking interruption to the law of a declining gradation W., in respect both of the aggregate depth of the Coal-measures and the number of included coal-seams presented by the Western Kentucky coal-district, is not a little anomalous, and suggests a doubt whether an error may not have been committed by the explorers of that coal-field, leading to an over-estimate of the thickness of the formation. It is a region intersected by a series of dislocated undulations of the strata, and by several faults of considerable magnitude ; and it is quite possible that through one or both of these sources of fallacious measurement certain parts of the Coal-measures may have chanced to be counted more than once.

The reader will find the composition of the coal strata of the Appalachian basin described at length in the Introduction to Book VIII. of this work, and again in the introductory Chapter of Book IX., on the Bituminous Coal-measures of Western Pennsylvania.

The limits of the several groups of the bituminous Coal-measures are indicated minutely on the Geological Map of Pennsylvania. To trace them in detail through the basin would demand a much more elaborate description than is compatible with the plan of this general outline. It will suffice for the present purpose to sketch the general boundary of the base of the upper productive group, or that which, in the ascending order, commences with the Great Pittsburg Coal-seam.

The basin or area of the Pittsburg Coal, and of all the Coal-measures which overlie it, has its Northern boundary in Western Pennsylvania, a little North of latitude 40° 30′. This boundary extends from Saltzburg, on the Connemaugh River, W. across the Alleghany River below Tarentum, and the Ohio River, near Little Sewickly Creek, in Alleghany County; and bending a little Southward, it recrosses the Ohio a short distance N. of Steubenville.

From the river-hills near Steubenville the margin of the upper productive group pursues a very nearly S.W. course to M^cConnellsville, on the Muskingum River, ranging through Jefferson County, the S.E. corner of Harrison, the N.W. corner of Belmont, and through Guernsey into the centre of Morgan. From the Muskingum it trends more nearly S., encroaching gradually towards the Ohio River, passing a little East of the town of Athens, and through the S.W. corner of Meigs County, and through Gallia County to the Ohio River, which it reaches a little above Burdington. The outcrop of the Pittsburg Coal-seam crosses the Ohio River near Brownsville, between the mouths of the Sandy and the Guyandotte rivers, and, curving rapidly towards the E., it sweeps across the Guyandotte, near the falls of that river, taking a nearly due East course thence to the Great Kenawha, the valley of which stream it passes below Charleston. Before reaching the Great Kenawha the line we are tracing turns N., and pursues an undulating N.E. direction parallel to the general course of the Elk River as far as Sutton in Braxton County, Virginia. From Elk River its general course is nearly N.N.E. to Pennsylvania; but the precise line of the outcrop is excessively winding, in consequence of the deeply-excavated character of the high sloping table-land through which it meanders E. of the valley of the Monongahela River; in this part of its course it traverses Braxton, Lewis, Barbour, Taylor, and Monongalia counties. From the point where it enters Pennsylvania, this margin of the upper Coal-measures pursues a very nearly straight course close along the base of Chestnut Ridge or West Laurel Hill, passing a little East of Uniontown, M^cConnellsville, Youngstown, and Blairsville, near which last-named place it reaches the N. boundary at the point from whence we set out.

The Pittsburg Coal, or main upper seam which constitutes the lower limit of the upper Coal-measures, evidently underlies every part of the large area thus defined: and this area appears to amount to about 14,000 square miles, of itself a very noble coal-field. Of course, each of the overlying coal-beds of the upper group possesses successively a less and less extent. It is probable that more than one of the thicker coal-beds of the lower Coal-measures have a continuous elliptical outcrop like the Pittsburg Seam, but this latter is at present the only member of the formation, the continuity of which has been positively established over so wide an area; and it is on this account particularly interesting—not merely as the widest seam of pure coal hitherto brought to light, but as manifesting in its broad extent and in the singular persistency of its characters and subdivisions, the wonderful uniformity of all the physical conditions under which its materials were accumulated. This prodigious floor of coal does not hold everywhere the thickness it possesses in South-western Pennsylvania, but undergoes a very gradual progressive reduction of size as it advances S.W. and S.; it declines, indeed, to a thickness of little more than 3 feet near the S. end of the oval basin which it occupies.

It is worthy of note that these upper Coal-measures bear the marks of having been formed under a considerably more uniform and tranquil condition than that which attended the deposition of the groups beneath them. Thus, not only do the sandstones, shales, and limestones maintain a more constant type, but the individual coal-seams themselves appear to fluctuate less in their dimensions and composition. This greater constancy of character is probably connected with a more marine or less littoral origin, as evinced in a larger proportion of limestones and other oceanic deposits, in a finer state of comminution of the land-derived sediments, and especially in a greater abundance of marine forms among the fossils. The evidences of these differences between the upper and lower Coal-measures may be abundantly seen in the detailed descriptions of them as they appear in Pennsylvania.

CHAPTER III.

ILLINOIS AND INDIANA COAL-FIELD.

General Description.—This great coal-field, embraced between the wide anticlinal area of the middle and older Palæozoic rocks of Indiana and Middle Kentucky on the E., and the anticlinal belt of Carboniferous limestones of the Upper Mississipp ion the W., is an immense tract of coal strata occupying the S.W. counties of Indiana, the Green River country of Kentucky, and a very large area of the extensive State of Illinois. The Coal-measures, or proper coal-formation, thus geographically defined, fill a tract of a somewhat regularly oval form, the longer diameter of the ellipse extending in a N.W. direction from near Morgantown in Kentucky to the Mississippi River, below Rock Island—a length of 375 miles. The greatest breadth of the elliptical coal-field is from Greencastle, W. of Indianopolis, to St Louis on the Mississippi, a distance of 200 miles. A careful estimate of its surface, as it is represented on the Geological Map, gives it an area of not less than 51,000 square miles.

According to Dr Norwood, workable beds of coal do not underlie the whole area thus estimated, and usually indicated on the maps as Coal-measures: he says,—

> "Illinois is not one 'great coal-field,' as has been represented in maps and geological reports made previous to the commencement of the State Geological Survey. While it contains within its borders more coal than any other State in the Union, with, perhaps, the exception of Pennsylvania, the coal does not rest in one great basin. So far as the State Survey has thrown any light on the subject, it has been found that the rocks beneath the Coal-measures, instead of showing a nearly horizontal section from E. to W., as was formerly believed by some of our geologists, have been in reality as much disturbed by internal convulsions as those of any volcanic district in the United States. The beds of the lower formations, including the mountain limestone and millstone grit,

are found, at various localities, displaced and tilted up at every angle from a few degrees to the vertical. These displacements are not confined to any one section: they occur in every district, from the N. limits of the coal-beds to the S. border of the State. In the irregular valleys and basins formed by these disturbances, our lower Coal-measures were formed. Subsequent to that period, the then existing coal-beds were displaced and eroded, forming new valleys and new basins which have been filled with new deposits of coal, and so on, up to the termination of the carboniferous epoch. An outline of these basins and valleys, so far as ascertained, will be given in the Geological Report. It must, however, remain imperfect for years to come, as every re-examination of a coal-field develops new facts, which no reasoning from previous data could have brought to light." *

As regards the coal-field itself, it has the structure of a comparatively shallow and rather symmetrical oval basin, or broad synclinal trough, with a general inward dip of the strata from all parts of the periphery towards the centre; but it is, as we have seen, not exempt from local undulations, containing, on the contrary, especially near its S.W. border, several wide anticlinal waves.

The greater part of the margin of the Illinois coal-field is bordered by a concentric outcrop of the Upper Carboniferous limestone, which, commencing N. of the Illinois River near La Salle, sweeps round the N.E. corner of the coal-field in a narrow belt, gradually widening in a S.E. direction until it crosses the Ohio River into Kentucky. From the Green River of Kentucky this limestone girdle trends in an undulating course W., N.W., and N., to the vicinity of Iowa City, passing the Ohio River in Hardin County, the Big Muddy River in Jackson, and the Mississippi River near the mouth of the Missouri; thence the belt runs N. between the coal-field and the Mississippi, which it crosses just above the Iowa River to enter the State of that name. The N. border of the coal-basin does not appear to be similarly confined by an outcrop of the carboniferous limestone, but is in contact with Palæozoic strata of the age of the Vergent or Chemung rocks, equivalents of the Middle Devonian strata of Europe.

The precise limits of the coal-bearing strata, for every part of the circumference of the basin, have not yet been established with precision; but we shall not err very widely if we define their boundary as ranging S.E. from the Illinois River, near the towns of Morris in Grundy County, Middleport, Iroquois, Covington, Greencastle, and Spencer, and thence, in a more nearly Southward line, to Rome on the Ohio River, and to Hardinsburg and Morgantown in Kentucky. From Morgantown, its general course is N.W., passing S. of Greenville and N.W. of Marion. Re-crossing the Ohio River into Illinois, it passes near the Sulphur Springs in Williamson County by Waterloo in Monroe, and near to Alton and Carrolton, until it crosses the Illinois River; beyond this it passes Beverley, and runs E. of Carthage and a little W. of Monmouth, until it meets the Mississippi River near Muscadine. Here the margin of the Coal-measures appears to deflect suddenly towards the E., and to extend parallel with the S. bank of the Mississippi River nearly to Rock Island, where, leaving the river, it stretches almost due E. across the State of Illinois to a point on the Illinois River a little N. of Ottowa, passing in its course a little N. of the town of La Salle.

The more prominent undulations in the S.W. boundary of the coal-field adjoining the Mississippi River would seem to be produced by tongues of the carboniferous limestone penetrating Northward into the general area of the coal-rocks, resulting from an undulation of the formations before the deposition of the coal.

---

* See *Abstract of a Report on Illinois Coals*, page 91. By J. G. Norwood, M.D., State Geologist.

I shall now proceed to offer a more detailed description of two or three of the better-explored local districts of this wide coal-field, commencing with a sketch of the strata as they are seen in Kentucky, the part nearest to the Great Appalachian coal-field already described.

WESTERN KENTUCKY COAL-FIELD.

Limits.—According to the Geological Report of Dr David Dale Owen, who has made a systematic survey of this coal-field of Western Kentucky, the portion of the Great Basin lying within that State covers the whole of eight counties, and a part of four others. The following is his description of its approximate boundaries:—

> "Commencing at the Ohio River, at the mouth of Tradewater, it runs up the valley of that stream, whose course very nearly coincides with its S.W. limits. From near the sources of Tradewater, in the N. part of Christian County, its S. boundary runs by the head-waters of Pond River, near the lines dividing Muhlenburg, Todd, Logan, and Butler counties, crossing Muddy River near its forks; thence through the S. part of Butler County, crossing Barren River between the mouth of Jasper River and the junction of Barren River and Green River; thence E. along the divide between those rivers, through Warren and Edmondson counties, to near the mouth of Nolin Creek; thence nearly N. to the mouth of Dismal. Either an outlier or tongue of the Coal-measures appears to stretch away to the E., to the confines of Grayson and Hart counties, and even on to the waters of Roundstone; but the main boundary takes from Dismal Creek a N.W. course S. of Grayson Springs, near the sources of Clay Lick and Caney Creeks, towards the falls of Rough Creek; thence N. by the sources of Panther Creek, nearly along the line dividing Hancock and Breckinridge counties, until it strikes the Ohio River again at the Great South Bend, near the limits of the above counties."

The formation is divisible into two groups, an upper and a lower set of Coal-measures; these are separated by a conspicuous sandstone called the "Anvil Rock." They are also geographically divided by a dislocated anticlinal axis, extending in a S.E. direction from Gold Hill, in Illinois, across the Ohio River at Shawneetown to Bald Hill in Union County. This dislocation casts off the Upper Coal-measures to the N., and the Lower to the S.

The subdivisions of the formation have been ascertained with approximate accuracy by surface measurements and borings, the general results of which are as follows: The estimated total thickness of the carboniferous strata in this coal-field is 3429 feet; the Lower Coal-measures, including the "Anvil Rock," being 1029, and the Upper Coal-measures about 2400 feet.

The number of coal-seams in the lower group amounts to *ten*, and all of these, excepting one called the "Curlew Bed," are workable. There are eight workable seams in the upper group, distributed through a thickness of about 2000 feet of strata. The upper 600 feet of the formation contain but one workable bed situated near the base of this division, which, however, includes nine other very thin bands of coal.

The united thickness of all these coal-seams, counting the thin ones with the thick, is upwards of 40 feet.

The accompanying columnar sections (Figs. 768, 769) will serve to convey a correct general notion of these Coal-measures.

In the W. portion of the coal-field the strata are thrown into "a series of waves or wrinkles, or into elongated dome-shaped vaults and corresponding depressions." One synclinal fold exists in the valley of Hines Creek; another trough or fold of depression enters the productive coal-field between Locust-Lick Creek and Tradewater River, and another at Half-Moon Lick on the Tradewater, extending nearly E. to Crab Orchard Creek. Between these are anticlinal flexures, forming with them a succession of waves.

Composition of the Coal.—The coal of this field is, for the most part, a tolerably pure bituminous coal, varying in specific gravity from 1.28 to 1.40, yielding generally from 50 to 60 per cent of coke. The average amount of volatile matter exceeds 40 per cent, and that of the ashes 5 or 6 per cent. The *colour* of the ashes or earthy matter of the lower group of coals is various, being, according to the seam, light-grey (corresponding to the white-ash of the lower anthracite beds), reddish-grey, and pale flesh-colour. A solid cubic foot of the coal weighs about 80 lb., and a cubic foot in lumps about 45 lb. The coal of some of these seams approaches in its qualities the splint coals of Scotland, having their dull aspect, and retaining, when coked, nearly the original shape of the coal. The reader will find the composition of several of these Kentucky coals in the table of "Analyses of Coals" in a future chapter.

"The compact slaty varieties of coal, like the Breckinridge Cannel Coal, yield about 60 per cent of volatile matter; the parrot coal, and even the bituminous shales, afford a vegetable tar, or thick crude oil, from which two products can be obtained; one of an oily consistence, which may be clarified into a nearly colourless oil, that, for certain purposes, may be substituted for other more expensive animal and vegetable oils; the other a transparent, scaly, crystalline substance, of a white colour and waxy lustre, which melts at 110° into a transparent oil, and at a still higher temperature takes fire and burns with a white flame, without smoke, and leaves no residue. This substance was called by the discoverer, M. Reichenbach, of Blansko, paraffin, from its little tendency to combine with other bodies.

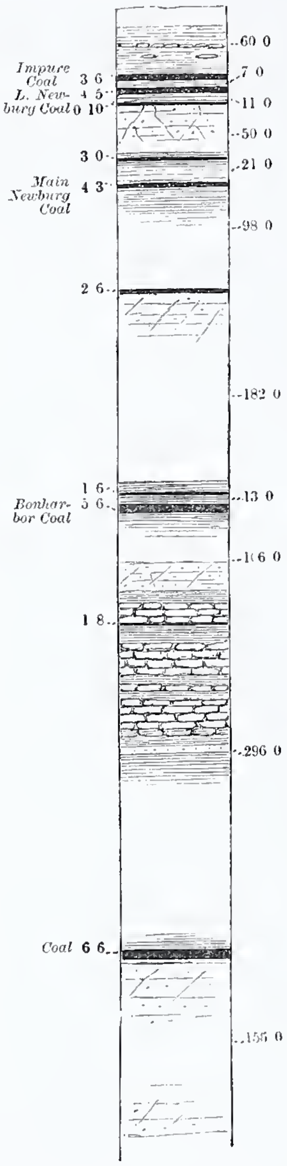


FIG. 768.—Upper Coal-measures, Holloway's Borings, Henderson County, Kentucky. From D. D. Owen. —200 *feet* = 1 *inch*.

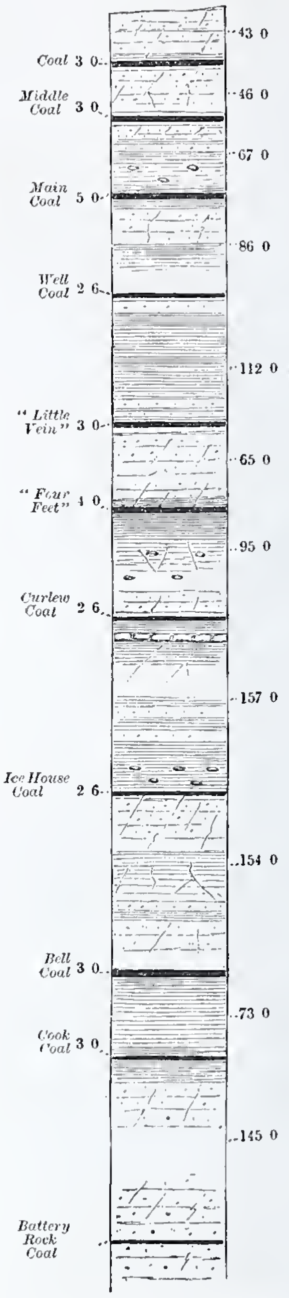


FIG. 769.—Lower Coal-measures of Kentucky. From D. D. Owen.—200 *feet* = 1 *inch*.

"It is supposed that the Breckinridge Coal may yield 25 per cent of refined oil, and 18 per cent of paraffin."

Iron Ores.—The intercalated shales of the Western Kentucky Coal-measures contain a fair proportion of the argillaceous iron-ores or clay iron-stones generally characteristic of Coal-measures. As generally in the Appalachian coal-field, these iron ores are most abundant in the lower group. They occur in the form of bands and flattened or kidney-shaped lumps. One stratum, a 10-feet-thick bed of shale, overlying a coal called the "Ice-House Seam," includes seven or eight thin bands of such iron ore, estimated to amount, in the aggregate, to a thickness of 16 inches. This ore is slightly calcareous, and well adapted to smelting, and promises to yield between 30 and 40 per cent of iron.

Other important beds of iron ore occur in the lower Coal-measures in Muhlenburg and Hopkins counties. "Considerable quantities of carbonate of iron are interstratified in the shales overlying the 'Thirteen-inch Coal' near low-water mark at Coal Haven and the head of French Island."

Limestones.—Bordering the Ohio River, the upper 400 feet of the Coal-measures are rich in limestones, there being five or six separate beds in this space; one of these, 8 feet thick, appears in the bank of the river one mile below Uniontown; another, 7 feet thick, occurs opposite Diamond Island; and a third bed, 8 feet thick, is in the hills of Green River near its mouth. Only two beds of limestone, worthy of note, are included in the lower 900 feet of the Coal-measures. One of these, 4 feet thick, lies below the "Curlew" Coal; the other overlies the coal next under the "Anvil Rock." It is stated that "the lower S. Coal-measures are richer in limestones than their S.W. equivalents."

The coal-seams of the Kentucky coal-field repose, in almost every instance, on a bed of fire-clay more or less pure, containing remains of the *Stigmaria ficoides*, or the roots of *Sigillaria*, one of the chief coal-producing plants of the coal period.

In 1857 there were eighteen coal-mines in operation on the Lower Ohio in this coal-field, though some of them were wrought on a very limited scale.

Undulations.—Two opposite views of the undulations of the Illinois coal-field have been entertained by the Western geologists, some explorers conceiving that the Coal-measures occur in detached basins, reposing unconformably upon the upturned edges of older Palæozoic strata, others believing that the basin structure is due to denudation upon the summits of anticlinal waves, embracing both those older rocks and the coal-formation. Both views would appear to be correct, for in the W. part of the Kentucky coal-field, the undulations of the Coal-measures involve the subjacent Middle and Lower Palæozoic rocks, whereas near La Salle, on the N.E. border of the Illinois portion of the basin, there prevails an actual unconformity of the Coal-measures to the subjacent strata. The probability is, that while some portions of the wide floor of the older rocks upon which the Coal-measures were deposited were disturbed from their original horizontality before the deposition of the coal, the whole coal-field was itself disturbed and undulated after the Coal-measures were formed, and the more exposed anticlinal waves were more or less denuded and separated.

Very little information has as yet been given to the world concerning the structure and contents of the middle tracts of this broad coal-field of Illinois. It has been stated that there exists in the interior of the basin a group of overlying strata referable by their organic remains not to the true Carboniferous formation, but to the still higher Permian series. But until the evidence from the fossils can be thoroughly sifted, we must remain in doubt whether to rank this upper group of strata as a higher division of the coal-formation, or as the representative of a separate and later age. According to Professor James Hall,* "the Coal-measures extend much farther to the N. than the Northern limits of the carboniferous limestones, and are spread out over the thinning and slightly-inclined edges of these beds, and over the more disturbed and more highly elevated edges of the rocks of the preceding periods, so that the Coal-measures rest respectively upon all the formations, from the lower Silurian to the carboniferous limestones." Dr J. G.

---

* See J. Hall "On Carboniferous Limestones of Mississippi Valley," in *Silliman's Journal*, vol. xxiii. p. 191.

Norwood reports that the coal-field is not a continuous one, but is broken into local patches by uplifts of the Carboniferous limestone. He describes the lower Coal-measures as deposited in basins thus produced, and as having undergone a subsequent disturbance, and states that this fracturing and filling up of the newly-formed valleys with fresh deposits of the coal strata, proceeded alternately to the end of the Carboniferous period.* According to Mr Worthen, the State Geologist, the general strike of the anticlinal axes disturbing the coal-field is N.W. and S.E.; parallel, that is to say, with the average longer diameter of the whole coal-basin, and not with the undulations of the Appalachian Chain. The same direction of the flexures has been noticed by Professor Hall in his traverse of the valley of the Upper Mississippi.

La Salle Coal-Field.—This N.E. division of the Great Illinois Coal-basin displays—according to Dr Norwood, who first made the discovery—the Coal-measures resting unconformably on the inclined strata of the Lower Silurian or older Palæozoic formations. The sandstone floor of the Coal-measures is in actual contact in some places with the Matinal (Trenton) limestone, identifiable by its fossils. The coal-field of La Salle is described by J. W. Foster, Esq.,† as occupying trough-like depressions in the older formations. The lowest seam sometimes reposes immediately on the edges of the older rocks, and at other times has a parting of shale. It is 3½ or 4 feet thick. An interval of 176 feet filled with shale, limestone, and thin beds of sandstone, separates it from the middle coal-bed, which is 6 feet thick, and contains a foot or more of cannel coal. Another space succeeds, containing a similar alternation of strata of 53 feet, surmounted by the upper coal-seam, which is nearly 4 feet thick. In this portion of the coal-field the strata dip at a very gentle rate, seldom much exceeding 5° towards the S.W. It is stated that these beds reappear in the cliffs of the Big Vermilion River.

According to Mr Foster, the coals of La Salle belong to the class of dry bituminous coals, their volatile matter amounting to from 25 to 30 per cent, uncombined water to more than 10 per cent, fixed carbon to from 50 to 60 per cent, and earthy matter 5 or 10 per cent.

The geographical positions of the Kentucky field in the S., and of the La Salle coal-field in the N., both occupying wide and comparatively unoccupied coal-markets, must promote the early and rapid development, by mining, of these interesting divisions of the basin; but the day cannot be distant when nearly every part of this great central coal-field of the Union will be much more thoroughly explored, and its vast stores of fuel made subservient to the demands of industry.

CHAPTER IV.

IOWA AND MISSOURI COAL-FIELD—GENERAL DESCRIPTION.

This very extensive coal-field stretches in a S. direction from the interior of Iowa across the Des-Moines and Missouri rivers to the lower valley of the Neosho in the Cherokee country, W. of Arkansas, where it appears to connect itself with the coal-field of the last-named State and the

---

* See *Abstract of a Report on Illinois Coals*, &c. Chicago, 1858.

† See *Report upon the Mineral Resources of the Illinois Central Railroad.* New York, 1856.

Indian territory. It is a rudely elliptical area, widest in the N., and contracting rapidly towards the S.W., in consequence of the S.W. trend of the older rocks which form its S.E. boundary in Missouri.

This coal-field is described by Dr D. D. Owen * as having in Iowa alone an average width from E. to W. of less than 200 miles; an average length of 140 miles, and an area of 25,000 square miles.

It is bounded, according to him, by an irregularly undulating line, as follows :—

"Commencing where the line between Iowa and Missouri crosses the Des-Moines River, near the W. border of Lee County; thence, nearly North, to the N.E. corner of Washington County; thence with a N.W. curve to the Iowa River, which it crosses in Township 81, North range 8 West, of the 5th Principal Meridian, not far from the line between Johnson and Iowa counties; thence up the valley of the Iowa some 25 miles, when it recrosses that river near the S.E. corner of Tama County; thence curving through Tama County, and again crossing the Iowa to near the centre of the E. line of Marshall County; thence along the water-shed of the Iowa and Cedar, recrossing the former near the N.E. corner of Township 87, North range 30 West, of the Principal Meridian; thence with a W. curve up the Iowa, and continuing W. of that river to the Big Woods, where it recrosses for a few miles, returning to the W. side of that stream, and running in a nearly due West course to the Des-Moines, which it crosses six miles above the Lizard Fork; thence with a S.W. curve towards the head-waters of the Three Rivers; thence down the valley of Neshnabotna to the State line.

"After crossing the Iowa boundary-line into Missouri, the boundary-line of this coal-field bears nearly S. through Clark, Lewis, and Marion counties, to near the junction of the Three Forks of Salt River. Thence through the W. part of Ralls County towards the head waters of Rivière au Cuivre, in the E. part of Audrain County, and N.W. corner of Montgomery County. Thence it sweeps in a South-westerly curve through Calloway County towards the Missouri River, which it crosses near its confluence with the Osage, leaving a belt of country, some 90 miles wide, between this coal-region and the outcrops at Charbonnière, and the coal-pits worked on Rivière des Péres, in St Louis County. These are, in fact, outliers of the Illinois coal-field. From the Missouri River the boundary bears, with a Westerly curve, up the valley of the Osage, N. of that river, which it crosses, but for a very limited distance only, at three points; in Camden County, near the mouth of the Niangua; in St Clair County, near the mouth of Sac River; and in Bates County, near the confluence with the main river of the Little Osage. Thence the line bears, with a Northerly curve, towards the W. confines of Fayette, recrossing the Missouri at Wellington, thence up the valley of that river to the State line, keeping from 10 to 25 miles from the river."

Later researches by the geologists of Missouri † indicate that the Coal-measures spread some distance into Nebraska and Kansas, or to the W. of the Missouri River, between the mouth of the Platte and the valley of the Neosho, but the W. limit of the productive coal-field has not yet been well defined.

Professor Swallow, in his Reports on the Geological Survey of Missouri, defines the area covered by the Coal-measures as bounded by a line drawn from the N.E. corner of Marion to the middle of the W. boundary of Jasper counties. This is the average boundary, "for the older rocks come to the surface in many places on the N.W. side of this line, as in the valleys of the Mississippi and Salt rivers, and of the Missouri as high up as Miami, in Saline County; while the coal strata are known to cover large areas in St Louis, St Charles, Calloway, Montgomery, Audrain, and Ralls counties to the S.E. of it." He estimates the area of the Coal-measures within the State as exceeding 26,887 square miles.

---

* See Owen's *Geological Survey of Wisconsin, Iowa, and Minnesota.* Philadelphia: Lippincott, Grambo, and Co.

† See *First and Second Annual Geological Reports of the Survey of Missouri*, by G. C. Swallow, State Geologist.

SUBDIVISIONS OF THE COAL-MEASURES.

Professor Swallow, in his Report, groups the coal-formation of Missouri into three subordinate series, the dividing rocks being two important sandstones. The lower series ranges N.E. from the S.W. corner of the State of Missouri, through Jasper, Bates, Sinclair, Henry, Benton, Morgan, Cooper, Boone, Calloway, Audrain, Monroe, Shelby, Marion, Lewis, and Clark, or from the Neosho to near the mouth of the Des-Moines, the S.E. margin forming one border of the coal-field.

It would seem that the Coal-measures, as they are intersected by the Missouri River, exhibit a prevailing Westerly dip, and do not present a regular synclinal structure or basin form, as indicated on the Geological Map of Dr D. D. Owen. The middle series, as a consequence, occupies the more central parts of the coal-field; it crosses the Missouri River between the mouth of the Kansas and the mouth of the Chariton, and ranges S. to Henry County, and N. and N.E. to the Grand and Chariton rivers. This middle group is well exposed in the sides of the Missouri Valley, near Lexington.

The upper or third division of the Coal-measures spreads along the Missouri River between Lexington and the mouth of the Platte, and is exposed at many localities between this last-named river and the Kansas, as at Parkville, Leavenworth, Weston, Elizabethtown, and Dallas.

Recent researches in Kansas have shown that these supposed Upper Coal-measures are overlaid in their turn by a still higher group of strata, recognisable by their organic remains as bearing an affinity to the Permian strata of Europe; but as no stratigraphical break or unconformity of any kind has been detected separating this later series of beds from the recognised Coal-measures, and as many of their fossils belong to the true Carboniferous species, the individuals of which, moreover, greatly exceed in number those of Permian analogies, it becomes us to be cautious in displacing these rocks from the proper Coal-measures to which they may possibly belong as a member of the American carboniferous system of deposits.

COMPOSITION OF THE COAL-MEASURES.

The *Lower Series* of the Missouri coal strata appear, according to the statements of Professor Swallow, to be inconstant in their lithological characters and their thickness. Between Booneville and the mouth of the La Mine their total thickness is about 150 feet; they there include six seams of coal, the lowest of which is 3 feet thick, and the fifth in ascending order 6 feet thick, while the other four are of dimensions less than 1½ feet. The other strata are chiefly bituminous shale, except that a bed of hydraulic limestone underlies the thickest of the coal-seams.

The Middle Coal-measures consist of brown and grey argillaceous sandstones, blue and yellow shales, and compact blue and buff limestones. Three permanent thin seams of bituminous coal occur in the shales of this group, and occasionally other still smaller layers. These rocks are less fossiliferous than the upper series. Their average thickness is about 200 feet.

The Upper Coal-measures consist of blue and grey bituminous shales, grey and buff limestones, and soft shaly sandstones, with several very thin layers of coal. Thin seams of coal occur also in the bituminous shales; but this division of the formation nowhere contains a coal-bed of sufficient thickness to admit of profitable mining. This series is estimated to have a thickness of about 300 feet.

It would appear from the foregoing statements that the total thickness of the Coal-measures on the Missouri River is 650 feet. On the line of the Hannibal and St Joseph Railroad their thickness is apparently 739 feet.

ORGANIC REMAINS.

According to the Report of Professor Swallow, the fossils become progressively more abundant as we ascend from the lowest to the highest strata of the Coal-measures; several species, however, *Fusulina cylindrica, Terebratula subtilita,* &c., are found throughout the three divisions.

The organic remains of these Missouri Coal-measures * consist of—

CRINOIDEA; 4 species of the genera *Echinocrinus, Poteriocrinus, Actinocrinus.*

ZOOPHYTES; 4 species of the genera *Chætetes, Zaphrentis, Campopyllum, Ceripora.*

BRACHIOPODA; 27 species of the genera *Productus, Chonetes, Orthis, Spirifer, Terebratula, Discina.*

ACEPHALA; 16 species of the genera *Allorisma, Myalina, Avicula, Pecten, Leda, Tellinomya, Cardiomorpha, Cardinia, Cypricardia, Arca, Pinna.*

GASTEROPODA; 12 species of the genera *Straparollus, Bellerophon, Turbo, Pleurotomaria, Loxonema, Murchisonia, Nerita, Fusulina.*

CEPHALOPODA; 5 species of the genera *Nautilus, Goniatites, Orthoceratites.*

CRUSTACEA; 1 species of the genus *Phillipsia.*

FISHES; teeth and bones of undetermined genera.

PLANTS; 4 species of the genera *Calamites, Sphæreda, Sigillaria, Lepidodendron.*

There are some remarkable deposits of coal and coal-shale in Missouri, detached from the general coal-field, and lying in very abnormal positions in ravines and excavations among the older formations as low as the Calciferous sandstone of the Auroral series; and it is a curious fact, that all the cannel coal hitherto discovered belongs to these insulated deposits. These outlying coal-beds, though usually circumscribed in extent, are in many cases of excellent quality, and of sufficient magnitude for mining.

IRON ORES.

The Coal-measures of Missouri are alleged to be generally deficient in the iron ores characteristic of other coal-fields. No deposits of clay iron-stone, or argillaceous protocarbonate of iron, have been met with of sufficient magnitude to be of any practical value.

CHAPTER V.

MICHIGAN COAL-FIELD.

THE next principal coal-field of the United States is that which occupies the interior of the Southern peninsula of Michigan. It is a broad, shallow coal-basin of an approximately circular outline, centrally situated between Lake Huron and Lake Michigan, and covering all the central counties of the State from Saginaw Bay on the E. to Wexford, Lake, Newago, and Kent counties on the W., and extending S. from the Manistee River to the head-waters of the Kalamasoo River. The E. margin of the Coal-measures, starting at Saginaw Bay in Huron County, runs S., trending a little W. through Tuscola County, passing the N.W. corner of Napier and the S.W. corner of Genessee, and through the W. side of Livingstone to the E. border of Jackson County. There the boundary curves W., and, crossing the S. portion of that county, deflects N.W., to maintain this latter direction through Calhoun and Barry to the Grand Rapids of the Grand River; passing which, its course is N. through Kent, Newago, and Lake, into Wexford, where it reaches the Manistee River. North of this stream it bends rapidly to the E., recrossing it in Kalkasta County, and extending through Crawford, near the E. border of which it bends again to run S.E. through Ogemaw and Losco counties to Saginaw Bay, which it reaches W. of Shawtimiog Point. The area of Coal-measures thus circumscribed is estimated at from 12,000 to 15,000 square miles. The S.E. and S.W. borders of the coal-field are marked by a narrow outcrop of the Carboniferous limestone, a formation which, in some localities, contains beds of gypseous shales, imbedding large cakes of plaster-of-Paris. Of the interior of the coal-field very little is known geologically. It is believed to embrace but few beds of coal of workable dimensions, probably only two or three. The strata, for the most part horizontal, or gently and widely undulated, consist mainly of shales and argillaceous sandstones. A general mantle of drift, or loose fragmentary matter, concealing the foundation-rocks of the country, and the surface being still further masked by a close covering of herbage and forest, the geological structure of this coal-field remains as yet very imperfectly known. We are led from general considerations, especially from the relationships of the strata underlying this coal-field to those which pass beneath the Great Appalachian and the Illinois basins, to conjecture that, at the termination of the coal period, or before the denudation of those lower rocks, these Michigan Coal-measures were continuous with those of the two other coal-fields; but more exact geological investigations are required before this and some other interesting questions in the geology of the country between Lake Erie and Lake Michigan can be satisfactorily settled.

---

* See Catalogue by Dr Shumard, page 16; *Geological Survey of Missouri.*

It is stated that coal outcrops at three different points—namely, at Barry in Jackson County, at Red Cedar River in Ingham County, and at Shiawassee River. The coal is compact and lustrous, ignites easily, and burns with a light flame, leaving but a small amount of ashes.

TABLE

SHOWING THE CHEMICAL CONSTITUTION AND PHYSICAL CHARACTERS OF THE BEST-KNOWN COALS OF NORTH AMERICA.

(BRITISH PROVINCES.)

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
"Main Seam," Sydney,	...	26.93	67.57	5.50	...	Prof. W. R. Johnson.	A bright free-burning coal, leaves a heavy reddish ash.
Carribou Cove, Richmond District,	...	25.2	44.7	30.1	...	Prof. J. W. Dawson.	A mixture of coal and bituminous shale.
Little River, Carribou Cove,	1.38	...	...	...	...	Do.	Hard, with uneven fracture, lamination rather indistinct; kindles quickly, and swells and cakes; ashes brownish.
Albion Coal, Pictou,	1.32	30.11	61.09	8.80	...	Do.	Is free from sulphur, but yields much light bulky ash; affords a good vesicular coke.
Pictou,	...	29.63	56.98	13.39	...	Prof. W. R. Johnson.	
Joggins Main Seam,	...	38.8	56.0	5.2	...	Prof. J. W. Dawson.	A bright coal; some iron pyrites and calcareous matter in its joints.
Springhill,	...	30.2	56.6	13.2	...	Do.	Compact, lustre rather dull, contains some sulphur.
Albert Mine,	1.09	57.6	42.4	.27	...	Hayes and Jackson.	Conchoidal, lustre resinous and shining, powder black, very brittle.

(UNITED STATES.)

	Names and Localities of Coals.	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.	Authorities.	Remarks.
Hard Anthracites.	Rhode Island,	1.79	3.00	77.00	16.00	...	Hayes.	
	PENNSYLVANIA.							
	Nesquehoning, 10-feet vein,	...	6.40	86.60	7.00	...	Geol. Survey, Penn.	Columnar, conchoidal, greyish black, splendent; ashes, white.
	Summit Mines of the Lehigh Company,	...	7.50	88.50	4.00	...	Do.	Massive, compact, black, brilliant; ashes, dull white.
	Summit Mines, Lehigh Company,	...	6.60	87.70	5.70	...	Do.	Dense, laminated, somewhat conchoidal, black, splendent; ashes, white.
	Tamaqua Coal D East,	1.57	5.03	92.07	2.90	...	Do.	Compact, slaty, conchoidal, greyish black, splendent; ashes, white.
	Tamaqua Coal E East,	1.60	4.54	89.20	6.26	...	Do.	Compact, conchoidal, greyish-black, splendent; ashes, pure white.
	Tamaqua Coal R, Sharp Mountain,	1.55	7.55	87.45	5.10	...	Do.	Compact, greyish-black, splendent.

	Names and Localities of Coals.	Composition.					Authorities.	Remarks.
		Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Hard Anthracites.	Tuscarora,	...	7.50	88.20	4.30	...	Geol. Survey, Penn.	Slightly laminated, compact, irregularly conchoidal, black, splendent; ashes, pinkish-brown.
	Beaver Meadow,	1.55	2.52	90.20	6.13	...	Prof. W. R. Johnson.	
	Schenoweth Bed, East Norwegian,	1.50	1.40	94.10	4.50	...	Do.	Compact, black, splendent; ashes, light brown.
	Third Coal, Nealy's Tunnel, near Pottsville,	1.55	5.40	89.20	5.40	...	Do.	Compact, iron-black, conchoidal, splendent; ashes, pale yellow.
	Forest Improvement,	1.47	3.07	90.70	4.41	...	Do.	
	Sharp Mountain, North of Pinegrove,	1.54	7.15	80.57	3.28	...	Geol. Survey, Penn.	Laminated, grey - black, splintery, splendent.
	Lyken's Valley,	1.39	6.88	83.84	9.25	...	Prof. W. R. Johnson.	
	Shamokin,	...	6.10	89.90	4.00	...	Do.	Massive, laminated.
	Black Spring Gap,	1.44	9.53	82.47	8.00	...	Do.	Friable, iron-black, somewhat splendent; ashes, yellowish white.
Semi-Anthracites.	Black Spring Gap, "Lea Vein,"	1.35	8.96	88.84	5.20	...	Do.	Laminated brittle black, shining; ashes, cream-colour.
	Black Spring Gap, "Grey Vein,"	1.44	9.78	81.62	9.20	...	Do.	Massive, black; ashes, light orange.
	Lyken's Valley, "Third Bed,"	...	8.85	88.25	2.90	...	Geol. Survey, Penn.	Laminated, brittle, fibrous, jet-black, shiny.
	Zerbe's Run,	1.40	7.31	84.25	6.11	...	Hayes, Mean of 5 Analyses.	
	Wilkesbarre, "Warden's Bed,"	1.40	7.68	88.90	3.49	...	Geol. Survey, Penn.	Compact, conchoidal, iron-black, splendent.
	Carbondale,	1.40	7.07	90.23	2.70	...	Do.	Laminated, compact, iron-black, brilliant; ashes, grey.
	Black Spring Gap, "Grey Band of Grey Vein,"	1.33	11.40	81.40	7.20	...	Do.	Fibrous, brittle, grey-black, smutty, dull, metallic lustre; ashes, pale ochreous yellow.
	Gold Mine Gap, "Peacock Vein,"	1.41	10.95	82.15	6.90	...	Do.	Massive, slightly columnar, black, shiny; ashes, pale orange.
	Gold Mine Gap, "Heister Vein,"	1.41	10.43	81.47	8.10	...	Do.	Massive, striated, jet-black, shining; ashes, pale yellow.
	Rausch Gap Dauphin, "Peacock Vein,"	1.45	10.57	77.23	12.30	...	Do.	Massive, friable, columnar, black; ashes, pale orange.
	Yellow Spring Gap,	1.41	10.95	79.55	9.50	...	Do.	Slaty, brittle, black, shining; ashes, pale yellow.
	Rattling Run, Dauphin,	...	13.75	74.55	11.70	...	Do.	Massive, fracture regular, black, shining, lustre feeble, yields a light and spongy coke.
Bituminous Coals, Semi-Bituminous, Cumberland (Maryland).	Big Flats,	...	15.06	76.94	8.00	...	Do.	Massive, laminated, striæ small, jet-black, much lustre, yields a good coal; ashes, orange.
	Broad Top (Hopewell Mine),	...	11.20	88.80	4.00	...	Do.	Somewhat columnar; yields a spongy coke.
	Blossburg,	1.32	15.27	73.11	10.77	0.85	Do.	
	Lycoming Creek,	1.38	14.48	71.53	13.96	0.03	Do.	
	New York and Maryland Mining Company,	1.43	14.10	73.50	12.40	...	Prof. W. R. Johnson.	
	Neffs,	1.33	15.13	74.53	10.34	...	Do.	
	Easby's "Coal in Store,"	1.30	15.65	76.27	8.08	...	Do.	
	Atkinson and Templeman's,	1.31	15.98	76.69	7.33	...	Do.	
	Easby and Smith's,	1.33	16.42	74.29	9.29	...	Do.	
	"Cumberland" (Navy Yard),	1.41	17.28	68.44	13.98	0.71	Do.	
	Lick Run, Lycoming County,	...	20.72	79.28	13.07	...	Do.	Laminated, somewhat brittle, shining, black.
	Queen's Run, below Farrandsville,	...	21.50	78.28	4.60	...	Do.	Irregularly columnar, brittle, jet-black, thin films of charcoal.
	Snoe Shoe Mine,	...	21.20	78.80	2.07	...	Do.	Massive, brittle, irregular, fracture tendency to columnar structure, jet-black.

	Names and Localities of Coals.	Composition.					Authorities.	Remarks.
		Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Bituminous Coals.	Moshannon Creek, near Philipsburg,	...	29.50	70.50	6.10	...	Prof. W. R. Johnson.	Small columnar, somewhat fibrous, striæ distinct, jet-black.
	Steed's Mine, 16 miles from Philipsburg,	...	20.40	79.60	120	...	Do.	Friable, irregularly columnar, striæ distinct, jet-black.
	Leech's Mine, 17½ miles from Philipsburg,	...	20.32	79.68	11.75	...	Do.	Friable, structure columnar, jet-black.
	Upper part of large bed, Ralston,	...	20.50	79.50	5.00	...	Do.	Columnar, irregular cubical, shining black.
	Karthaus Lower Seam,	...	24.80	75.20	4.70	...	Do.	Columnar, cubical, friable, jet-black.
	Reed's 6-feet Vein, Curwinsville,	...	27.00	73.00	5.30	...	Do.	Columnar, cubical, brittle, jet-black, with great lustre.
	Bear Creek, Blossburg,	...	32.00	68.00	5.20	...	Do.	Columnar, somewhat compact thin seams of charcoal, lustre jet-black.
	Warner's 5-feet Vein, Caledonia,	...	37.00	63.00	8.50	...	Do.	Laminated, cubical, brittle, jet-black.
	Warner's 3-feet Seam, Caledonia,	...	38.20	61.80	7.20	...	Do.	Soft, columnar, jet-black, fracture irregular.
	Blairsville Large Bed,	...	31.00	69.00	4.00	...	Do.	Laminated, columnar, hard, compact, shining, jet-black.
	Sandy Ridge, 4 miles from Shippensville,	...	43.20	56.80	7.00	...	Do.	Massive, striæ indistinct, fracture cubical, black, lustre feebly shining.
	Cannel Coal, from 6 miles East of Franklin,	...	52.78	47.22	17.68	...	Do.	Composed of laminæ, breaks with uniform cleavage, conchoidal, dull-black, with little lustre.
	Cannel Coal from Greensburg,	...	36.00	64.00	33.88	...	Do.	Thick regular laminæ, cross fracture, conchoidal, surface smooth, dull black.
	Conneaut Lake,	...	38.75	61.25	1.80	...	Do.	Slaty, laminated, somewhat brittle, jet-black.
	Near Greenville,	...	40.50	59.50	1.7	...	Do.	Laminated, slaty, cross fracture, splintery, brittle, jet-black.
	Near Orangeville,	...	43.75	56.25	2.80	...	Do.	Laminated, rusty between laminæ, black, sometimes iridescent.
	VIRGINIA.							
	Little Sewell,	...	17.48	80.24	2.28	...	Prof. W. B. Rogers.	Shining and dull-black laminæ.
	East side of Big Sewell, Rogers' Seam,	...	22.32	75.88	1.80	...	Do.	Shining jet-black laminæ, some dull-black.
	West flank of Big Sewell, Tyree's Bed,	...	30.08	67.84	2.08	...	Do.	Dull-black laminæ.
	Between Big Sewell and Kenawha, Paris and Wood's Bank, Mill Creek, Fayette County,	...	26.20	71.88	1.92	...	Do.	Shining black laminæ, films of charcoal.
	Valley of the Kenawha. Lower Coal Series. Keller's Creek, Lowest Seam,	...	37.08	60.92	2.00	...	Do.	Brilliant, compact.
	L. Ruffner's Campbell Creek, or Second Seam,	...	32.44	55.76	11.80	...	Do.	
	Noyes, Rand, & Co.'s Campbell Creek or Second Seam,	...	31.28	65.64	3.08	...	Do.	
	Cox and Hannah's Third Seam,	...	42.55	51.41	6.04	...	Do.	Black, shining, compact.
	Faure's Bank, Upper Seam,	...	35.04	53.20	11.76	...	Do.	
	Smither's Bank,	...	29.76	54.52	15.76	...	Do.	
	Hughes Bank,	...	32.88	62.32	4.80	...	Do.	Brilliant, compact.
	Daniel Ruffner's Upper Seam,	...	35.08	57.28	7.64	...	Do.	
	Brantzburg, Lower Seam, North Branch of Potomac,	...	19.72	72.40	7.88	...	Do.	
	Oliver's Tract, 12-feet Seam,	...	16.28	79.08	4.64	...	Do.	
	Sigler's Mine, near Westernport, Maryland, 12-feet Seam,	...	15.76	82.60	2.64	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Lonaconing, Maryland, 12-feet Seam,	...	19.37	77.43	3.20	...	Prof. W. B. Rogers.	
Kitzmiller's, Hardy County,	...	15.48	79.76	4.76	...	Do.	
Falls of Stony River, Hardy County, Lower Seam,	...	15.52	79.16	5.32	...	Do.	
Stony River, 1 mile North of Turnpike,	...	13.28	83.36	3.36	...	Do.	
Colonel Fairfax's Kingwood Basin, Upper Seam,	...	31.75	53.77	14.48	...	Do.	
Do. do. Middle Seam, 2½ miles from Kingwood,	...	27.77	65.32	6.91	...	Do.	
Forman's Basin, South-East of Kingwood Basin,	...	21.00	73.68	5.32	...	Do.	
Forman's Mill, Big Sandy, 1 mile from Brandonville, Preston County, Middle Seam,	...	22.40	67.60	10.00	...	Do.	
Mr Seaport's Big Sandy Basin, West side of Big Sandy River,	...	27.12	66.64	6.24	...	Do.	
Mr Hagan's Kingwood Basin, 1 mile West of Kingwood,	...	26.48	68.32	5.20	...	Do.	
Mr Cresap's, three-fourths of a mile South-West of Kingwood,	...	30.24	64.24	5.32	...	Do.	
Main Seam, Clarksburg Upper Coal series,	...	41.66	56.74	1.60	...	Do.	
Main Seam, near the middle, Clarksburg,	...	45.43	49.21	5.36	...	Do.	
Main Seam, Pruntytown (same with the Clarksburg Seam),	...	39.00	57.60	3.40	...	Do.	
Main Seam, Morgantown (same with the preceding),	...	37.30	60.54	2.14	...	Do.	
Judge Summer's Bank, Coal Creek, Kenawha,	...	41.85	55.55	2.60	...	Do.	Compact, thin laminæ, striated, shining, jet black.
Judge Summer's Vein, Grand Creek, Kenawha,	...	43.20	52.75	4.05	...	Do.	Compact, fracture irregular, jet black.
Wolf Creek, half a mile above the Burning Spring, Big Sandy,	...	48.00	47.15	4.85	...	Do.	Laminated, shining, jet black, striæ indistinct.
Big Coal River, 5 miles above the junction of the two branches,	...	47.10	50.20	2.70	...	Do.	Cleaves into laminæ, jet shining black, striæ indistinct.
Three-Mile Creek, Kenawha County,	...	50.30	45.95	3.75	...	Do.	Semi-compact, laminated, dull-black.
Lawson's Opening, Logan Court-house,	...	39.50	58.35	2.15	...	Do.	Massive, shining jet black.
Traa Fork, Guyandotte,	...	42.00	56.50	1.50	...	Do.	Massive, columnar, dull-black.
Pigeon Creek, Big Sandy River,	...	41.00	55.00	4.00	...	Do.	Shining jet black, laminæ.
Coals of the Chesterfield, Powhatan, Goochland, and Henrico Basins. Coals from South side of James' River. Clover Hill,	...	33.04	56.83	10.13	...	Prof. W. R. Johnson.	
Mid-Lothian,	...	32.09	63.11	4.80	0.99	Do.	
Stonehenge,	...	36.50	58.70	4.80	...	Prof. W. B. Rogers.	Ashes, light reddish.
Engine Shaft, Maidenhead,	...	32.83	63.97	3.20	...	Do.	Ashes, strong red.
Engine Shaft, worked by Heth, Potts, & Co.,	...	37.65	62.35	2.80	...	Do.	Ashes, reddish yellow.
Wills's Pit,	...	32.50	62.90	4.60	...	Do.	Ashes, light brown.
Colonel Heth's deep shaft, bottom of the seam,	...	35.82	53.36	10.82	...	Do.	Ashes, light pinkish-brown.
Powhatan Pits,	...	32.33	59.87	7.80	...	Do.	Ashes, pale buff.
Winterpock Creek, Appomatox River, Mr Cox's Mine,	...	29.12	65.52	5.36	...	Do.	
Coals from near the North side of James' River. Anderson's Pit, First Seam in Shaft,	...	28.30	66.78	4.92	...	Do.	Ashes, light grey.
Barr's Pits, First Seam,	...	24.00	70.80	5.20	...	Do.	Ashes, faint red.
Deep Run Pits,	...	25.16	69.84	5.00	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
KENTUCKY.							
"Thirty-Inch Coal," near Racoon Creek, Greenup County, .	1.32	41.20	50.20	8.60	1.44	Dr D. D. Owen.	Slaty, tough, dull-black. A splint coal.
Racoon Creek, under part of 8 to 10 inch Coal, near Racoon Furnace, ...	1.39	35.50	55.30	9.20	0.45	Do.	A dry splint coal; ashes nearly white.
Bottom part of Main Peach Orchard Coal, Lawrence County,	1.27	38.6	58.55	2.85	...	Do.	
Main Ashland Coal, below the clay-parting, Greenup County,	1.33	44.1	51.4	4.5	...	Do.	Ashes, reddish-grey.
Crawford's Cannel Coal, near Grayson, Carter County, .	1.21	59.0	34.5	6.5	...	Do.	Ashes, flesh-colour.
Gairt's Main Coal, Big Sandy, 5-Mile Shoal, Lawrence County,	1.30	41.2	53.8	5.0	...	Do.	Ashes, light grey.
McHenry's Coal, Tugg Fork of Big Sandy, Lawrence County, .	1.31	40.0	50.0	10.0	...	Do.	Ashes, whitish grey.
Aron's and Bogg's Coal, Big Sandy Coal, and Mining Company, Floyd and Johnson Counties, .	...	35.2	63.8	1.0	...	Do.	Ashes, flesh-coloured.
Main Ashland Coal, above clay-parting, Greenup County, .	1.28	38.30	57.90	3.80	0.73	Do.	Soft, "fat," bituminous, deep pitch-black, strong lustre; ashes, purplish grey.
Coal, with slate roof, first bed above Ashland Main Coal, Greenup County, . . .	1.30	40.70	51.00	8.30	1.81	Do.	Intensely black coal, high lustre; ashes, lilac-coloured.
Kilgore's Coal, William's Creek, Carter County, ...	1.31	41.00	55.00	4.00	0.71	Do.	A splint coal, pitch-black, lustrous; ashes, pale grey.
Cannel Coal from Barrett's Creek, Carter County, ...	1.44	37.50	42.70	19.80	8.00	Do.	Dull, slaty, jet-like lustre; ashes, dark lilac colour.
Airdrie Coal, 6¼ feet thick, Muhlenburg County, ...	1.22	48.40	48.50	3.10	1.35	Do.	Pure, soft, friable, shining pitch-black; ashes, reddish grey.
Eade's Coal, 2½ miles S.W. of Greenville Muhlenburg County,	1.26	40.40	56.10	3.50	0.65	Do.	Ashes, purplish.
Clark's Coal, Pond River, Muhlenburg County, ...	1.34	33.30	59.20	7.50	0.55	Do.	Friable, dull, fragmentary; ashes, nearly white.
Todd and Crittenden's Coal, Owsley County, ...	1.29	36.80	57.10	6.43	0.33	Do.	Pitch-black, much lustre, fibrous, splint coal; ashes, nearly white.
Cannel Coal from Haddock's Mine, Owsley County, . . .	1.21	50.00	47.00	3.00	0.24	Do.	Tough, pitch-black, conchoidal; ashes, buff-coloured.
Coal, Cumberland River, Whitley County, ...	1.29	39.00	57.00	4.00	...	Do.	Ashes, light grey.
Cannel Coal, Dorton's Branch, Cumberland River, . . .	1.25	42.9	55.1	2.0	...	Do.	Close-textured, concentric-structured, brilliant, conchoidal; ashes, orange-coloured.
Coals of Edmondson County, First Coal, ...	1.29	40.0	40.0	20.0	...	Do.	
Coals of Edmondson County, Second Coal, ...	1.29	45.2	53.8	5.0	...	Do.	
Main Coal, Giger's Hill, Catlettsburg, Greenup County, . .	1.21	40.00	57.80	2.20	0.26	Do.	Bituminous, pitch-black, strong lustre; ashes, yellowish grey.
Coal from Hoskin's Mine, Short Mountain, ...	1.33	37.8	55.2	7.0	...	Do.	Ashes, purplish grey.
Coal, Kincheloe's Bluff, or Lewisport, Green River, . . .	1.27	43.0	55.0	2.0	...	Do.	
Colonel Martins' Coal, above Prestonburg, Big Sandy, . .	...	38.0	61.0	1.0	...	Do.	
Pittsburg Coal, ...	1.29	31.70	65.30	3.00	0.05	Do.	Pure-looking, pitch-black, much lustre; ashes, yellowish grey.
Lower part of First Coal under the Anvil Rock, Union County, .	1.36	39.6	47.4	13.0	...	Do.	Ashes, reddish grey.
Mr Hawes' Main Coal, Howesville, Hancock County, . .	1.39	47.0	46.0	7.0	...	Do.	Ashes, white.
Roberts' Coal, Muddy River, Muhlenburg County, . .	1.21	41.48	54.72	3.80	...	Do.	Ashes, white.

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
Captain Davis' Jakefield Coal, Hopkins County,	1.29	43.75	50.75	5.50	...	Dr D. D. Owen.	Ashes, nearly white.
Gamblin Coal, Hopkins County,	1.27	42.47	56 13	1.40	...	Do.	Ashes, pale flesh-colour.
Box Mountain Spring Coal, Hopkins County,	1.33	40.75	50.25	9.00	...	Do.	Ashes, light greyish flesh-colour.
Captain Davis' Pigeon Run Coal, Hopkins County,	1.28	46.8	49.7	3.5	...	Do.	Ashes, white.
Big Sandy Main Coal, Lawrence County,	...	35.2	63.8	1.0	...	Do.	
Cook's Coal, Green River, Henderson County,	...	44.5	47.0	8.5	...	Do.	
Bonharbor Coal, Daviess County,	1.27	48.3	46.7	5.0	...	Do.	Ashes, light grey, almost white.
Two inches of coal on the top of Bonharbor Coal,	1.52	38.0	37.0	25.0	...	Do.	Hard, close-textured, compact, cannel-like.
Wolf Hill Coal, Daviess County,	1.22	42.4	56.6	1.0	...	Do.	
Two-feet Henderson Coal, equivalent of the Little Newbury,	...	45.5	44.5	10.0	...	Do.	Ashes, grey.
Gallion's Coal, William's Creek, Carter County,	1.31	45.80	49.50	4.70	2.41	Do.	Pitch-black, strong lustre; ashes, dark lilac colour.
Keath's Coal, near Pond River, N.E. part of Christian County,	1.30	43.90	48.90	7.20	2.16	Do.	Soft, friable, dull, pitch-black; ashes, pale reddish grey.
Lacey's Atchison's Coal, Pond River, N.E. part of Christian County,	1.27	41.70	53.30	5.00	1.36	Do.	Soft, bituminous, pitch-black, lustrous; ashes, lilac-coloured.
Robert and A. G. Carter's, Bath County,	1.32	38.00	53.90	8.10	0.99	Do.	A splint coal, fibrous, pitch-black lustre; ashes, light-grey colour.
Mulford's Main or Five-feet Coal, Union County,	1.30	39.5	57.5	3.0	...	Do.	
Bell's Coal, Crittendon County,	1.27	39.4	57.6	3.0	...	Do.	Ashes, pale flesh-colour.
Mulford's Four-foot Bed of Coal, Union County,	1.28	42.4	50.6	7.0	...	Do.	Ashes, light grey.
"Little Vein," Mulford's Mine, Union County,	1.30	36.7	55.3	8.0	...	Do.	Ashes, light grey.
Little Vein, Cannel part,	1.36	40.3	47.7	12.0	...	Do.	
Mulford's Middle Coal, Union County,	1.40	38.7	51.3	10.0	...	Do.	Ashes, reddish grey.
Ice-House Coal, Union County,	1.34	36.5	58.5	5.0	...	Do.	Ashes, reddish grey.
Upper part of First Coal under the Anvil Rock, Union County,	1.28	51.3	42.3	9.0	...	Do.	Ashes, reddish grey.
Wright's Mountain Coal, Hopkins County,	1.28	41.40	56.30	2.30	0.10	Do.	Pure-looking, soft, friable; ashes, dark grey.
Robinson's Coal, Clear Creek, Hopkins County,	1.27	45.50	51.10	3.40	1.56	Do.	Soft, pitch-black; ashes, reddish grey.
Pond River Coal, near McNary's, Hopkins County,	1.29	40.30	53.50	6.20	1.12	Do.	Ochreous, pure, pitch-black, lustrous; ashes, dark brick red.
Tygert's Coal-bank, Hickory Camp Creek, Butler County,	1.29	38.60	56.90	4.50	0.29	Do.	Friable, pitch-black; ashes, light yellowish grey.
Pardon Sheldon's Coal, Welch Creek, Butler County,	1.24	38.70	60.70	0.60	0.26	Do.	Pure-looking, soft, pitchy-black, strong lustre; ashes, dirty salmon colour.
Sneed's Coal Mines, Tradewater, Crittenden County,	1.31	37.00	55.40	7.60	1.04	Do.	Very black, pure, bituminous; ashes, purplish grey.
Caseyville, Cannelton Coal,	1.39	31.82	44.49	23.69	...	Prof. W. R. Johnson.	
INDIANA.							
Cannelton,	...	38.16	58.34	3.50	...	Do.	
SOUTHERN ILLINOIS.							
Saline River, Galatin County, Upper Bed,	...	42.4	56.1	1.5	...	Dr Norwood.	
Saline River, Second Bed,	1.28	36.8	55.2	8.0	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
Saline River, lowest bed worked,	1.29	40.8	55.5	3.7	...	Dr Norwood.	
Saline River, Upper Bed Lock Reserve,	1.30	39.2	57.8	3.0	...	Do.	
Eagle Creek, Galatin,	1.23	37.0	57.2	5.8	...	Do.	Ashes, grey.
Bowles,	1.30	39.8	53.2	7.0	...	Do.	Ashes, white.
Equality, Lower Bed,	1.29	35.8	52.2	12.0	...	Do.	
Equality, Upper Bed,	1.30	37.7	59.8	2.5	...	Do.	
Equality, Top Bed, Martin's,	1.27	40.66	51.92	6.7	...	Do.	Ashes, drab.
Coal Branch of Bankston Creek, Saline County,	1.28	39.08	50.6	9.6	...	Do.	
Hay's Mill, Little Saline River, Saline County,	1.49	32.04	57.6	10.0	...	Do.	Ashes, dark red.
Dr Smith's, Williamson County,	1.31	40.1	51.92	8.7	...	Do.	Ashes, reddish brown.
Spiller's, Williamson County,	1.28	43.1	54.9	2.0	...	Do.	
Joel Johnson's, Johnson County,	1.44	25.6	47.84	27.1	...	Do.	Ashes, white.
Murphreysboro', Jackson County,	1.29	37.7	60.8	1.5	...	Do.	
Shasteen, Hamilton County,	1.32	38.94	53.56	7.5	...	Do.	Ashes, pale brown.
Du Quoin, Perry County,	1.28	48.9	48.1	3.0	...	Do.	Ashes, grey.
Schneider's, Munroe County,	1.24	42.9	52.6	4.5	...	Do.	Ashes, white.
Schneider's, Lower Bed,	1.28	41.0	52.2	6.8	...	Do.	
Caseyville, Six-Feet Bed, St Clair County,	1.30	39.8	55.2	5.0	...	Do.	Ashes, pale red.
Pfeiffers, St Clair,	1.29	44.3	51.2	4.5	...	Do.	Ashes, red.
Belleville, St Clair,	1.26	45.0	49.6	5.4	...	Do.	Ashes, grey.
Belsha's Middle Drift, St Clair,	1.29	43.66	47.74	8.6	...	Do.	Ashes, grey.
Dilg and Kempff's, Belleville, Middle St Clair,	1.38	42.38	49.02	8.6	...	Do.	Ashes, white.
Dilg and Kempff's Top Coal, St Clair,	1.28	45.54	47.66	6.8	...	Do.	Ashes, white.
Dilg and Kempff's Bottom Coal, St Clair,	1.35	39.63	36.77	23.6	...	Do.	Ashes, grey.
W. B. Churchill's, St Clair,	1.31	45.4	45.7	8.9	...	Do.	Ashes, white.
Jeffrey's, Madison County,	1.28	48.75	47.35	3.9	...	Do.	Ashes, grey.
Cartlidge's, Madison,	1.31	44.39	45.01	10.6	...	Do.	Ashes, grey.
Groshang's, Madison,	1.32	37.55	54.85	7.6	...	Do.	Ashes, brown.
Dumford's, near Alton, Madison,	1.25	47.26	47.44	5.3	...	Do.	Ashes, grey.
Emerson and Ryder's, Madison,	1.31	42.6	53.9	3.5	...	Do.	Ashes, reddish brown.
Wood River, Middle Bench, Madison,	1.31	50.0	42.7	7.3	...	Do.	Ashes, pink.
Wood River, Upper Bench,	1.29	55.3	37.2	7.5	...	Do.	Ashes, grey.
Cook's, Madison,	1.30	51.15	38.85	10.0	...	Do.	Ashes, grey.
Edwardsville, Madison,	1.34	46.85	49.75	3.4	...	Do.	Ashes, purplish.
MIDDLE ILLINOIS.							
Johnson's, Calhoun County,	1.26	45.7	49.1	5.2	...	Do.	Ashes, brown.
Near Carbinville, Macoupin,	1.27	43.48	48.72	7.8	...	Do.	Ashes, grey.
Houseworth's, near Pittsfield, Pike County,	1.22	49.5	45.5	5.0	...	Do.	Ashes, white.
Jackson's, near Pittsfield,	1.77	14.1	56.9	29.0	...	Do.	Ashes, grey.
Drake's, Green County,	1.30	40.47	48.93	10.6	...	Do.	Ashes, grey.
Sander's, North of Springfield, Langamon County,	1.24	48.14	42.86	9.0	...	Do.	
Springfield, Langamon,	1.28	53.9	42.8	3.3	...	Do.	Ashes, dark grey.
Puffenberger's, Langamon,	1.26	50.68	43.62	5.7	...	Do.	Ashes, dark brown.
Pleasant View, Schuyler County,	1.28	40.6	52.9	6.5	...	Do.	Ashes, deep red.
Rushville, Schuyler County,	1.30	41.6	46.1	12.3	...	Do.	Ashes, white.
Exeter, Scott County,	1.28	42.37	50.13	7.5	...	Do.	Ashes, red.
Barker's, Scott County,	1.23	42.8	52.2	5.0	...	Do.	Ashes, light brown.
Frost's, Scott County,	1.28	46.37	46.53	7.1	...	Do.	Ashes, red.
Higby's, Adams County,	1.33	48.4	41.2	10.4	...	Do.	Ashes, yellow.
Bassett's, Adams County,	1.26	42.52	51.48	6.0	...	Do.	Ashes, pale red.
Payne's, in entry, Vermilion County,	1.28	47.0	47.5	5.5	...	Do.	Ashes, grey.
Payne's, in outcrop, Vermilion,	1.26	46.1	43.9	10.0	...	Do.	Ashes, grey.
Henson's, Vermilion,	1.31	43.5	50.0	6.5	...	Do.	
Lafferty's, Six-Feet Bed, Vermilion,	1.28	44.3	48.7	7.0	...	Do.	Ashes, grey.

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
Carother's, Vermilion,	1.21	50.8	46.2	3.0	...	Dr Norwood.	Ashes, greyish white.
Gilbert's, Vermilion,	1.21	51.4	45.6	3.0	...	Do.	
Butler's, Vermilion,	1.39	40.1	47.9	12.0	...	Do.	Ashes, grey.
Leonard's, Vermilion,	1.31	45.57	48.93	5.5	...	Do.	Ashes, white.
William's, Vermilion,	1.22	49.15	45.85	5.0	...	Do.	
Alexander's, Vermilion,	1.26	43.5	40.5	16.0	...	Do.	
Russell's, Vermilion,	1.21	49.0	39.0	12.0	...	Do.	Ashes, grey.
Chicago and Danville Coal Company, Vermilion,	1.23	49.04	48.96	2.0	...	Do.	Ashes, bluish grey.
Cook's, Vermilion,	1.33	47.3	47.7	5.0	...	Do.	Ashes, reddish grey.
Eli Thornton's, Vermilion,	1.40	42.27	55.73	2.0	...	Do.	Ashes, red.
J. H. Blackmore's,	1.29	44.5	47.10	8.4	...	Do.	Ashes, reddish grey.
Colchester, McDonnough County,	1.29	41.2	56.8	2.0	...	Do.	Ashes, light grey.
Opposite Peoria, Tazewell County,	1.26	43.4	48.6	8.0	...	Do.	Ashes, grey.
Salem Hill, Menard County,	1.26	46.0	51.2	2.8	...	Do.	Ashes, very dark red.
NORTHERN ILLINOIS.							
Kickapoo, Peoria County,	1.28	47.7	46.3	6.0	...	Do.	Ashes, grey.
McMurtry's, Knox County,	1.21	50.5	45.5	4.0	...	Do.	Ashes, nearly black.
Loomis, Wataga, Knox,	1.28	44.4	51.1	4.5	...	Do.	Ashes, pink.
Loomis, Cannel Coal, Knox,	1.33	42.4	33.6	24.0	...	Do.	Ashes, grey.
Smith's, Warren County,	1.24	43.1	51.7	5.2	...	Do.	Ashes, red.
Tucker's, Warren,	1.22	44.8	51.0	4.2	...	Do.	Ashes, red.
Sheffield, Bureau County,	1.19	47.5	47.5	5.0	...	Do.	Ashes, white.
Tiskilwa, Bureau County,	1.36	43.0	48.9	8.1	...	Do.	Ashes, white.
Rock Island, Shale, Rock Island County,	1.44	31.3	46.7	22.0	...	Do.	Ashes, light red.
Carbon Cliff, Rock Island,	1.24	43.7	52.8	3.5	...	Do.	Ashes, white.
Corcoran's, Rock Island,	1.26	47.2	50.3	2.5	...	Do.	Ashes, black.
Robbin's, Henry County,	1.22	49.7	47.1	3.2	...	Do.	Ashes, blackish grey.
Aldrich's, Henry,	1.26	43.1	49.9	7.0	...	Do.	Ashes, brown.
Kewanee, Henry,	1.23	42.2	52.8	5.0	...	Do.	Ashes, grey.
Geneseo, Henry,	1.32	41.24	52.76	6.0	...	Do.	Ashes, brown.
Thornton and Park's, Mercer County,	1.24	45.8	49.7	4.5	...	Do.	Ashes, white.
Perley's Ottawa, La Salle County,	1.26	43.7	52.3	4.0	...	Do.	Ashes, white.
Ward's, Marseille's, La Salle,	1.31	45.6	33.4	21.0	...	Do.	Ashes, white.
Hitt's Vermilion Mine, La Salle,	1.29	46.9	40.3	12.8	...	Do.	Ashes, white.
Kirkpatrick's, Big Vermilion, La Salle,	1.20	48.2	49.3	2.5	...	Do.	Ashes, grey.
Ireland's, La Salle,	1.23	46.7	50.3	3.0	...	Do.	Ashes, grey.
Seeley's Lowell, La Salle,	1.22	42.6	41.4	16.0	...	Do.	Ashes, bright brick red.
Kirkpatrick's Cannel Coal, La Salle,	1.43	39.6	30.4	30.0	...	Do.	Ashes, grey.
Eagle Creek, La Salle,	1.22	46.7	45.8	7.5	...	Do.	Ashes, dark red.
Buffalo Rock, La Salle,	1.28	45.0	50.5	4.5	...	Do.	Ashes, pale red.
Big Vermilion, La Salle,	1.24	51.4	47.1	1.5	...	Do.	
Eglston's Cannel Coal, La Salle,	1.41	44.5	41.5	14.0	...	Do.	
Field and Round's, La Salle,	1.22	48.1	46.7	5.2	...	Do.	Ashes, red.
Kirkpatrick's Cannel Coal, La Salle,	1.26	45.2	40.1	14.7	...	Do.	Ashes, blackish grey.
Egleston's, La Salle,	1.21	48.25	48.45	3.3	...	Do.	Ashes, grey.
Hartshorne's, La Salle,	1.27	42.5	49.7	7.8	...	Do.	Ashes, brown.
Kentucky's Coal Mining Company, Upper Bed, La Salle,	1.25	52.51	40.49	7.0	...	Do.	Ashes, brown.
Gorbett's, La Salle,	1.25	45.18	47.12	7.7	...	Do.	Ashes, red.
Kentucky Shaft, La Salle,	1.26	42.93	50.07	7.0	...	Do.	Ashes, purplish.
Peru, La Salle,	1.53	28.68	40.32	31.0	...	Do.	Ashes, brown.
Watson's, Grundy County,	1.25	45.5	47.8	6.7	...	Do.	Ashes, pink.
Turner's, Morris, Grundy,	1.22	48.5	49.0	2.5	...	Do.	Ashes, white.
Eight Miles South-West of Wilmington, Grundy,	1.21	47.95	49.15	2.9	...	Do.	
MISSOURI.							
Osage River,	1.20	43.50	51.16	5.34	...	Prof. W. R. Johnson.	

BRITISH COAL-FIELDS.

THE Carboniferous System of Great Britain occupies the Western and Midland parts of the Island, extending, with slight interruptions, from South Wales, or the Bristol Channel, to the estuaries of the Firth of Clyde in Scotland. This Carboniferous system succeeds the Devonian or Old Red Sandstone formation, which, in its turn, reposes on the older Palæozoic or Silurian system. In England the Carboniferous system is generally composed of five groups of strata, the whole of which, however, are not always present in particular localities. They are as follows, beginning with the uppermost :—

1. Coal-seams, alternating with sandstone and shale.
2. Millstone-grit.
3. Yordale rocks, shales, limestone, and gritstones.
4. Scar limestone, or mountain limestone.
5. Shales.

... ...

The Carboniferous or Mountain Limestone forms the base of the Coal-measures. In North and South Wales, in Derbyshire, Somersetshire, and Gloucestershire, it forms one unbroken band, with a thickness varying from 1900 feet to 400 and 500 feet, and frequently rises to the surface. As it passes N., however, through Lancashire, Cumberland, and Northumberland, to the Tweed, it becomes more and more divided by beds of sandstone and shales, till at Aldstone Moor no less than twenty of these bands, having an aggregate thickness of 470 feet, are found alternating with shales and coal-seams.

Throughout all this range, though the aspect of the limestone varies somewhat, yet it preserves nearly a uniform mineral character. It is nearly a pure carbonate of lime, of a greyish or bluish-grey colour, passing to blocks of considerable hardness, and with a conchoidal fracture. Many varieties, on being rubbed or bruised, exhale a fœtid odour. Sometimes it contains an admixture of clay and of carbonate of magnesia, at other times it forms with sandstone a brecciated mass. It is full of organic remains, chiefly *corals, encrinites, Producta, Spiriferæ, Terebratulæ,*— all indicative of its marine origin.

Solid bitumen is frequently found imbedded in this limestone. Chert nodules, and other silicified masses, are prevalent ; and in Derbyshire the limestone is intersected by an igneous rock called Toadstone.

The Yordale rocks, common in Derbyshire and Yorkshire, consist of shaly limestone of a black or brown colour, and a micaceous gritstone, with an average thickness of 500 feet. The dark argillaceous limestone contains an abundance of marine shells, *Goniatites, Orthoceratites,* and *Posidoniæ,* having their cavities filled with liquid bitumen. It is of importance to notice that the lower coal-shales of Ireland contain exactly similar beds of bituminous shaly limestone as the above.

Millstone-Grit.—This sandstone bed, immediately below the coal-seams, is a coarse-grained sandstone, identical in its component parts with the sandstones of the coal strata. It is made up of quartz pebbles, of various sizes under that of an egg ; of felspar, in small rounded masses, having internally a crystalline structure ; and of pale silvery fragmentary scales of mica sparingly intermixed ; the whole cemented by a soft, whitish, unctuous mass of decomposed felspar.

The millstone-grit of the S. of England is more compact, harder, and more cherty than the coarse pebbly conglomerate of the N. districts ; it furnishes a good building-stone in Yorkshire, Lancashire, and Derbyshire, and under the name of "Farewell Rock" in Dean Forest and South Wales, is a valuable stone for the construction of iron furnaces, as it is found to resist great heat.

The Coal-Measures.—These consist of alternating strata of sandstone, shale, coal, and ironstone.

The sandstone beds, of varying thickness, consist of the same materials as the millstone-grit, but are generally softer and more argillaceous. They both indicate an origin from decomposed granites, or similar crystalline rocks. Iron nodules, marine shells, *Goniatites, Unios, Pectens,* and, in some localities, shells of fresh-water molluscs, together with the usual fossil plants of the coal-formation, are common to the true Coal-measures, as well as the accompanying shales, grits, and sandstones.

The chief workable coal-fields of Great Britain consist of the South Wales basin, the Dean Forest, Gloucestershire, the great central and Western coal-field extending through Nottinghamshire, Derbyshire, Yorkshire, Durham, Northumberland, and on the West through Cheshire, Lancashire, Westmoreland, Cumberland, a distance of 200 miles in length, with an average breadth of 60 miles ; the coal-fields of Berwickshire and Dumfriesshire in Scotland, and the great Scottish basin, extending from the mouth of the Firth of Forth on the E., to the mouth of the Clyde on the W. shores.

The Great South Wales Coal-Field.—This extensive deposit occupies the N.W. portion of the Bristol Channel, extending from St Bride's Bay on the W., to Pontypool on the E., a distance of 90 miles, the maximum breadth being about 60 miles. It is divided into two parallel basins by a longitudinal axis of elevation. The depth from the carboniferous limestone to the uppermost coal-series is computed at 12,000 feet,* and the depth of the true Coal-measures 8000 feet. There are 23 beds of workable coal, with an aggregate thickness of 92 feet—12 beds are from 3 to 9 feet thick, 11 from 18 inches to 3 feet, with numerous others from 6 to 18 inches thick.

The nature of the coal varies at different points even in the same beds. On the N.E. side is a coking coal, well suited for the manufacture of iron ; on the N. the coal or culm is an anthracite ; on the S. side, from Pontypool to Caermarthen Bay, it is of a bituminous quality.

There are at least sixteen layers of ironstone and iron nodules in thin beds. No trap-dykes or igneous rocks in any form enter this basin, though syenitic rocks adjoin it in Pembrokeshire.

The South Wales coals are shipped for the supply of the S.W. coast of England, and for Ireland, as also Spain, France, Malta, and Egypt.

Home consumpt and exports in 1841, ... 4,800,000 tons.
Price of anthracite coal from 8s. to 10s. per ton ;—other coals from 7s. to 10s. and 11s. per ton.

The Welsh semi-bituminous coal is similar to that of Pennsylvania, and is in request as steam coal.

Anthracite is employed largely in South Wales in the iron manufactories, which have of late years rapidly multiplied there.

In 1854 the amount of anthracite coal raised in Glamorgan and Pembroke shires was .	1,000,000 tons.
Of bituminous coal from Monmouth and Glamorgan shires, ...	7,500,000 „
There were exported by sea, coastwise, in the same year, of coals, coke, and culm, .	2,065,957† „
Exported to foreign countries, do., ...	829,058 „

North Wales Basin.—This basin lies S. of the estuary of the Dee in Flintshire, and extends from N. to S. upwards of 30 miles. The coal shales rest upon the Silurian slate of Selattyn Mountain, and dip generally E., forming, in the N. part, a trough below the estuary of the Dee ; from thence they rise on the E. side of that estuary, and, sinking below the red sandstone, extend to the river Mersey, and probably join the Lancashire coal-beds. The seams are of various thicknesses, from 2 to 15 feet, and consist of the common bituminous and cannel coals.

Forest of Dean.—This small isolated basin lies on the E. side of the estuary of the Severn in Gloucestershire. It contains twenty-seven seams, with an aggregate thickness of 37 feet of coal, mostly soft-burning, but in the lower seams of a coking quality.

Coalbrookdale.—This small coal-field, about 12 miles in length, is situated in Shropshire, on the E. slopes of the Wrekin. There are various coal-beds, forming an aggregate thickness of from 16 to 55 feet, the whole greatly broken up by the intrusion of trap rocks and dykes. The coal is slaty-bituminous, frequently sulphurous. Cannel coal is rare ; petroleum abounds in the centre and upper part of the field.

Broken patches of coal strata lie on the S. side of the valley of the Severn, along the vale of Shrewsbury.

South Staffordshire Coal-Field.—This field extends 20 miles from N. to S., and about 7 miles in breadth, including Dudley, Bilston, and Cannock Chase. In the centre of the field a saddle-shaped anticlinal ridge of the Wenlock limestone of the Silurian system rises up, upon the summit of which is built Dudley Castle. The Coal-measures lie on each side of this limestone, and are traversed from N.W. to S.E. by a basaltic dyke, which causes numerous faults in the strata. The new red sandstone lies above the Coal-measures ; the millstone-grit is absent below, and the strata are mostly argillaceous, interspersed with ironstone, the only valuable seams of which are near the base of the series.

The coal-seams are numerous, and vary in thickness from 9 inches to upwards of 30 feet. Only the lower seams are workable. The aggregate thickness of coal near Dudley is about 57 feet, and between Bilston and Wolverhampton upwards of 70 feet.‡ The seams crop out, and are lost to the N. of Walsall. The coal-seams are classed into three divisions, the great "Ten-yard Seam" being the chief. This "main seam" lies near Dudley, at a depth of 360 feet. It is composed of thirteen different beds, separated by thin partings, which in some places swell out into considerable extent, the greatest aggregate thickness amounting to 39 feet. Each of these divisions has its particular name, and is characterised by varying qualities of coal. The middle portions are the best, and are used for household purposes ; about one-half is inferior, and is used only in the ironworks. The coal does not cake, but burns freely, leaving a white ash. Cannel coal is found in some of the seams of this coal-field to a limited extent.

From the basaltic masses which traverse the coal-field, wedge-like portions pass off laterally into the seams, and at the points of junction the coal appears to have been altered by the heat of the igneous rocks.

There are seventy coal-pits worked in this district. The deepest workings are 780 feet, the shallowest 120 feet. About 2000 miners are employed. The celebrated Stourbridge fire-bricks are manufactured here ; and large quantities of iron are produced, amounting in 1846 to half a million tons. In 1837 there were conveyed by canals from this district 2,091,596 tons of coal. In 1854, from 531 collieries in Staffordshire and Worcestershire there were raised 7,500,000 tons of coal.

---

* De la Beche. † *Mining Records.* ‡ JUKE'S *Records of School of Mines.* § *Mining Records.*

North Staffordshire Coal-Field.—This field, broken up by numerous faults, contains a valuable series of coal-seams. About thirty-two beds have been determined, and their numerous workings supply the populous district of the Potteries.

Bristol Coal-Field.—This field occupies a surface of about 50 square miles around the city of Bristol, besides numerous other beds to the W. and the S. detached from the main basin.

The coal strata here have undergone intricate upheavals and depressions, forming anticlinal, synclinal, and variously-waved arrangements; they are, besides, covered by thick beds of new red sandstone and lias, which render them still more difficult of investigation. Below are irregular belts of old red sandstone, mountain limestone, and millstone-grit. The coal strata, according to De la Beche, consist of the following series:—

Upper shales and sandstones,	1800 feet, with	10 beds of coal,	18 feet 3 inches.
Middle sandstones (Pennant grit),	1725 do.	5 do.	10 feet.
Lower shales, . . .	1565 do.	36 do.	72 feet.
Farewell rock, &c., . .	1200		
Forming an aggregate of	6290 feet.		

The thickness assigned to the coal includes partings, and in the lower shales an admixture of under-clay. Ironstone is not common in this district.

Notwithstanding the thinness of the individual seams, and the difficulties and expense of working them, a large amount of coal is now mined. In 1854 there were forty-five collieries in operation, and 1,050,500 tons of coal were raised.*

THE YORKSHIRE AND GREAT CENTRAL COAL-FIELD.

This field extends from N. to S. a distance of about 60 miles, stretching from the middle of Yorkshire to Nottingham, its broadest part being between Halifax and Went Bridge. Here the strata dip regularly and at a moderate angle to the S.E.

This coal-deposit is characterised by three divisions, thus—above, magnesian limestone, unconformable to the Coal-measures:—

UPPER SERIES, ...	Shales and thin seams of inferior coal. Ackworth Sandstones. Two seams of coal worked at Wragby and Sharlston. Coarse red sandstone, as at Wooly Hooton, &c.
MIDDLE SERIES, ...	Furnace coals, Barnsley thick coal. Intermediate coal, Rock of Herbury, middle coal. Ironstone coals, Silkstone and Flockstone beds, Low Moor coals. Flagstone, a fine-grained micaceous slaty sandstone.
LOWER SERIES, OR GANISTER,	Shales and *Ganister*—a hard silicious sandstone. Coal. Shales and *Ganister.* Coal. Shale. Millstone-grit.

The lower series is included between the millstone-grit and flagstone, and has a thickness of from 360 to 450 feet. Near the bottom are two thin seams of coal, from 16 to 30 inches, which are workable, with several other thinner layers scattered through the mass. One of the larger seams, which can be traced through a wide range, is remarkable for its roof, which, instead of having its usual covering of shale, with remains of fresh-water plants, is filled with a number of marine shells belonging to the genera *Pecten*, *Goniatites*, and in one locality *Orthocera;* also nodular concretions, enclosing *Posidonia* and scaly fishes. The Ganister stone, which also prevails in this lower series, is a hard silicious sandstone, similar to the Crow-stone of the mountain limestone series in Swaledale. This stone in some instances forms the floor of the coal-seams, a circumstance never observed in the upper coal-series of the district, which invariably rest on a fine clay, full of Stigmaria roots;† while the *Goniatites*, *Nautili*, *Pectens*, and *Orthocera*, which are found in the cover of the seams, are analogous and in part identical with fossils of the mountain limestone. In these respects this *Ganister* series corresponds to the upper limestone series of the Penine chain, and with the millstone-grit series of Derbyshire; but near Halifax it is also found to contain fresh-water *Unios*, similar to those found in the upper coal-series of Northumberland and Derbyshire. Two layers of these shells occur—one of them about the middle of the series, considerably above the *Pecten* coal; the other near the bottom, and considerably below that coal. It would thus appear that during the formation of the successive beds of this lower series, the locality had been more than once subjected to the dominion of the sea.

The Flagstone, which lies intermediate between the lower and middle series, forms a thick deposit of fine-grained micaceous sandstones, which readily separate into slaty layers, and which are extensively used over the whole district as a building and roofing stone. In many localities this rock exhibits vegetable remains. *Equisetaceous* impressions are abundant in the flagstones of Leeds, accompanied by trihedral fruits; but *Lepidodendra* and *Sigillariæ* occur less frequently.

---

* HUNT, *Mining Records.*

† PHILLIPS'S *Geology.*

The middle series is the most valuable, and contains ten workable seams of coal of various quality, with several layers of ironstone bands, one of which is full of fresh-water bivalve shells.

The upper series lies on the coarse reddish sandstone and shales of Wooly Edge. These differ from the sandstones and shales of the lower groups in containing no layers of marine shells, no productive beds of ironstone, few vegetable remains, and coal of inferior quality, being earthy and less bituminous. Two workable coal-seams occur near the bottom, and one or two thinner seams are near the top. This seems to exhaust the coal-deposit, and magnesian limestone succeeds by a well-defined and distinct line of separation.

No trap-dykes intersect the Yorkshire coal-district, but there occur many faults, some passing nearly E.N.E. and W.N.W., and others nearly N.N.W. and S.S.E.

In 1854 there were 7,260,500 tons of coal raised in the West Riding of Yorkshire, the greater proportion of which was consumed in the extensive manufacturing towns of the district, and in the iron manufactories.

The Ashby-de-la-Zouch Coal-Field is separated into two bands by an anticlinal flexure of mountain limestone, which, like some of that of Derbyshire, contains a large admixture of magnesia. One coal-band, made up of several others, has a thickness of from 17 to 21 feet. The coal is generally of a hard quality. There is one seam of cannel coal.

In the Derbyshire Coal-Field, about twenty beds, having an aggregate thickness of 60 feet, are workable.* The strata are much disturbed by faults, but generally lie in a regular manner. About 30 feet on the E. side are attainable, and yield largely. The varieties yielded are anthracite, bituminous, and cannel coals.

The Nottingham Coals are similar to those of Derbyshire. The general characters of this central district resemble those of the great Yorkshire coal-field. The same millstone-grit and shales lie beneath both. The lower part of the series contains the most bituminous coals; in the middle is the best ironstone, the shale of which contains fresh-water shells; and above are fast-burning coals. The thickest bed in the district is the same as the Ten-feet Seam in Yorkshire.

Around Halifax, the coal which belongs to the lower series is of inferior quality, and only fit for iron-smelting. At Newton colliery, near Leeds, seven seams are wrought, containing about 18 feet of coal. A shaft near Wakefield has a depth of 290 yards.

The Lancashire and Yorkshire Coal-Field.—This important deposit adjoins on the W. the central coal-field, and is separated from the Carboniferous system of the North of England by the intervention of the Penine chain of mountains. The field is of an irregular form, but, including the millstone-grit, it extends from Macclesfield on the S. to Colme on the N.—a distance of 56 miles; and from Torbock, near Liverpool, to Todmorden on the N.E., about 40 miles. Exclusive of the millstone-grit, it occupies an area of about 250 square miles. This area includes the productive portion of the field, the remainder extending over the millstone-grit, and containing scattered and thin beds of coal. The district includes Manchester, Liverpool, Bolton, Oldham, and other manufacturing towns.

In a section from Manchester to Hollin's Brook, the depth of strata, including the millstone-grit, is 6000 feet, in which are imbedded seventy-five seams of coal, each not less than 1 foot thick, and forming an aggregate thickness of 150 feet. In another section, through Worsley, Bury, and Burnley, to the limestone shales of Pendle Hill, there are thirty-six seams of coal, ten of them not exceeding 1 foot in thickness, and making in all 93 feet of coal. In West Lancashire the thickness of workable coal is about 80 feet, and the total thickness of strata upwards of 6000 feet. Mr Binney divides the coal-field into three groups:—

1. The Upper or Manchester series, containing a bed of limestone, with fossil fishes and marine shells.
2. A middle series, containing the thickest seams, and the cannel coal of Wigan.
3. The lower seams, of no great thickness, corresponding to the Ganister series of Yorkshire, with marine fossils, *Goniatites*, *Posidonia*, and *Pectens*.

The bituminous coals are distinguished into two kinds—the cubical, where the cross cleavage runs at right angles to the main cleavage; and the rhomboidal, where it makes an acute angle. Cannel coal is found in the lower part of the middle series, and along with it fossil fishes and shells, but rarely vegetable remains. The Wigan cannel and Orell coals are highly hydrogenous. Upwards of 6,000,000 tons of coal are annually raised from this district. Price (1840), Orell 14s. 6d., River 11s., Cannel 20s. per ton.

At Patricroft is a seam of coal 6 feet thick, at the depth of 1350 feet. At Pendleton, near Manchester, the shaft is sunk to 1521 feet.

Extensive faults divide the Lancaster coal-field. At Pendleton the "red-rock fault" causes a dislocation of strata to the extent of 3000 feet. Near Wigan a series of faults range nearly N.N.W. and S.S.E., causing upthrows and downthrows of from 500 to 1600 feet.

Coal-Field of Durham and Newcastle.—This field extends from the river Tees to the Coquet, about 55 miles, with a breadth of about 15 miles, and includes an area of 780 square miles. Part of the E. side is covered by the magnesian limestone and red sandstone of the Permian series. If the millstone-grit and shale were included, the above area would be doubled. About three-fourths of the coal-field lie in the county of Durham.

Though these coal-fields are separated at the surface from those of Yorkshire and Derbyshire by about 60 miles, yet the strata have such a general correspondence in both as to lead to the conclusion that they are of one formation, and perhaps connected towards their borders, and in the deeper parts of the deposit. Both are superimposed upon a bed of coarse pebbly sandstone or grit, with the mountain limestone below. The coal-seams in both have a corresponding resemblance. The upper seams consist of coals abounding in volatile matter; the lower seams contain bituminous coals of excellent quality. Ironstone is most plentiful in the middle and lower part; and the "*muscle-bands,*" composed of marine bivalves, which are so conspicuous in the great central field, are also found to some extent in the N. deposits. Lastly, unconformable beds of magnesian limestone cover portions of the upper strata of both basins.

---

* PHILLIPS'S *Geology*.

The total thickness of the strata is upwards of 1600 feet; the aggregate thickness of the coal-beds about 60 feet; but the workable beds do not exceed 30 feet of aggregate thickness. The thickest bed does not exceed 6 feet. Dividing the strata into three sections, we have—

1. *Upper Series,* consisting of eight or nine thin beds of coal of little value, interstratified with a variety of sandstones and shales, with ironstones, and a muscleband forming the base. Total thickness, 900 feet.

2. *Middle Group.*—At the top the *High Main Coal-Seam,* 6 feet thick; then various strata of shales and thin coal, with three seams of coal, each 3 feet in thickness, forming 423 feet, followed by the *Low Main Seam,* 6 feet in thickness.

3. *Lower Series,* consisting of sandstone and shale of the thickness of 700 feet, with two beds of coal, each 3 feet thick.

Numerous trap-dykes traverse this coal-field—two in particular, "the Ninety-Fathom Dyke," which runs along the valley of the Tyne to the sea-cliff N. of Tynemouth; and the "Cockfield Fell Dyke," in the S. part of the county of Durham, which crosses the district from W.N.W. to S.S.E. Many of these dykes, crossing the coal-seams, have charred the coal in the neighbourhood.

A system of natural fissures, called "Cleats," prevails throughout the district in a direction from N.N.W. to S.S.E.

Many of the coal-shafts about Newcastle are from 1000 to 1200 feet deep; that of Monkwearmouth, near Sunderland, is 1674 feet; the S. Helton shaft in Durham County is 1488 feet.

The water from the deep shafts of the Tyne and Wear is impregnated with chloride of soda, lime, and magnesia.

The greater portion of the coals of this district are of the bituminous coking kinds, but there are several varieties. The High Main and Wallsend coals are highly esteemed in the London market. The best coke for engines is made from the Auckland districts of Durham, and Shotley Bridge district of Northumberland. The best steam-coal is got from the N. side of the Tyne and the Blythe district.

The Newcastle coals obtained an early celebrity, and were extensively exported. In 1813 there were no less than four millions of tons raised in this district; and though the other coal districts of England and Wales now largely compete with it, the home consumption for 1843 was 4,711,000 tons, and the export from the various ports of the district, both for home and foreign consumption, amounted in the same year to 6,123,000 tons. It is interesting to observe the rapid increase of the consumption of coal within the period of 140 years. In 1710 the total exports from this district only amounted to 820,000 tons. In 1854 there were raised from the districts of Northumberland and Durham 15,420,615 tons of coal, more than one half of which was exported by sea, or carried by railway to other districts, as in the following summary :—

	Tons.
Coal and coke exported to foreign countries,	2,766,098
Coals and coke sent coastwise (to London 3,252,000 tons),	5,830,439
Coals and coke sent to and exported from Maryport and Port Carlisle,	92,014
Coals sent inland by various railways,	3,032,064
Coals used in ironworks within the districts,	1,200,000
Coals consumed at collieries,	1,100,000
Coals for local consumption and manufactures,	1,400,000
	15,420,615*

Cumberland Coal-Field.—This field forms a narrow crescent, extending from Whitehaven to near Hesket, Newmarket, and below the Irish Sea. The curve is about 40 miles in length, with a mean breadth of 3 miles, forming an area of 120 square miles. Seven productive beds are worked at Howgill, to the W. of Whitehaven, at a depth of 600 and 900 feet, and the workings are carried 3000 feet under the sea. At Preston How, the coal-shaft, after passing several thin beds, comes to a bed 5 feet thick, and a little lower to a bed with 8 feet of coal. This coal burns at first with a clear flame, and ultimately forms a cake. Professor Sedgwick divides this coal-field into two divisons, the upper containing the *Great Main* and *Bannock bands,* the lower containing five beds of inferior quality. A fault on the W. of the field produces a downcast to the S.W. of 1000 feet. To the W. of this the coal-seams dip into the sea; to the S. the dip is reversed.

At Sobergham, near Hesket, a seam of coal nearly 3 feet thick is worked, which partakes of the characters of an anthracite and cannel coal—a semi-anthracite. To the W. of Appleby, in Westmoreland, there are three detached coal-basins, forming together about 26 square miles.

---

* *Mining Records,* 1855.

In 1854 there were raised in this district 887,000 tons of coal, of which 580,000 tons were shipped from the neighbouring seaports, and 36,000 tons used at the iron-founderies.

Great deposits of hæmatitic iron-ore are found in the limestones in the vicinity of Whitehaven, and between Ulverstone and Furness.

SCOTCH COAL-FIELDS.

The Carboniferous system of Scotland occupies a trough formed by the great Grampian range of mountains on the N., and the Lammermoors on the S., through which flows on the E. the river Forth, and on the W. the Clyde, with their expanding estuaries. Along the N. and S. edges of this great trough appears the Old Red Sandstone formation, on which the Coal-measures rest.

A series of trap-rocks intersect this hollow trough with an evident range from W. to E., but appearing on the surface irregularly, and causing considerable elevations and undulations of the country; and these igneous rocks have also broken up the original continuity of the coal-field, and separated it into numerous belts.

The general outlines of the great Scottish coal-basin are easily defined. On the S., a line drawn from near the town of Haddington, in East Lothian, extending along the base of the Lammermoors, passing through the upper part of Lanarkshire, and terminating at Turnberry Castle in Ayrshire, will bound this formation; and a line from St Andrews in the E. coast of Fife, extending along the S. banks of the River Eden, and the S. edge of the Ochil Hills, passing through Stirlingshire, Dumbartonshire, and the N. part of Renfrewshire, will limit its Northern extent. It thus embraces an area of about 90 miles in length, with a mean breadth of 30 miles, the workable coal-surface being estimated at about 1500 square miles. It will thus be apparent that at the era of the coal-deposit there existed a hollow trough between the Primary range of the Grampians on the N., and the lower Silurian mountains on the S., the base of which trough was formed of old red sandstone; and that, subsequent to the coal-deposit, the valley was elevated, by the agency intruding the trap-rocks, to the position which it now holds.

The Coal-measures of this district consist generally of the following alternations of strata, beginning with the uppermost:—

1. Sandstone and Shales.
2. Coal and Ironstone.
3. Limestones, various beds.
4. Old Red Sandstone.

The millstone-grit of the English coal-fields is here wanting, the lower limestones and shales resting on the old red sandstone. There are from five to six district bands of limestone, varying in thickness from 3 to 30 and 40 feet. These bands are found in the lower half of the series, and the thickest beds are in the lowest part of this half. The limestone beds generally contain marine shells exclusively, but there are others interspersed which contain *Unios* and land-plants, with an absence of marine fossils, and these are generally considered to be of fresh-water origin. The E. part of this coal district in the Lothians has an aggregate thickness of 6000 feet in the centre, but it thins out towards the edges. In Lanarkshire the thickness is great, but the thickness of individual strata, especially of the sandstones, as well as the aggregate thickness of the whole deposits, varies much in different localities. All the coal-basins of the district are more or less intersected by trap-dykes and faults, and where the trap-rocks have come into contact with the coal-seams, shales, and sandstones, the action of heat is evident from the altered structure of these latter.

The general character of the sandstone is that of a fine-grained mass, interspersed with mica of a white, yellowish, or reddish colour; in some places, as near Glasgow, it is of a reddish-blue tint, and coarse-grained; in others, as at Killaloe in Fifeshire, it is nearly pure white. Beds of conglomerate alternate with the more compact sandstone. The usual coal-fossils, *Stigmariæ*, *Lepidodendra*, *Ulodendrons*, *Sigillariæ*, *Equisetaceæ*, and *ferns*, abound in the strata, and large fossil *Coniferæ* are frequently found from 20 to 40 feet in length, imbedded in and intersecting the shales and sandstones.

From position and other circumstances, it has been conjectured that the Scottish coal-fields are deposits of earlier date than those of England. The coal is generally of the kinds called splint, cubical, bituminous, and cannel coal, of varying degrees of richness. The bituminous coals, with a few exceptions, are not of the caking kind, but burn with a steady heat and flame, generally leaving a considerable quantity of white and reddish ash. Some of the cannels, as the Torbanehill, Methil, and Lesmahago, are highly hydrogenous.

In the coal-mines of Scotland the spontaneous evolution of hydrogen gas or fire-damp is little known. The Lothian coal-field is entirely free from this, though it occurs occasionally in Ayrshire, and still more rarely in Fife. Carbonic acid gas, or "choke damp," is not uncommon, and, accumulating in the lower parts of the mines, sometimes proves fatal.

The coal-formation first appears in the S. of Scotland, in irregular patches along the N. slopes of the Cheviot Mountains, which separate this country from the N. of England.

The carboniferous strata of Berwickshire occupy a triangular space on the N. and S. banks of the Tweed, extending from the town of Berwick to Kelso.

To the N. are Silurian strata in highly-inclined positions; on these rests the Old Red Sandstone. Immediately succeeding this latter are about eight bands of mountain limestone, with intermediate beds of sandstone. The lowermost limestone-bed is of considerable thickness, and forms the bold shores to the N. of Berwick. To this succeed beds of white sandstone resembling that of the Lothians, interstratified with shale, with numerous vegetable impressions, and in some places thin seams of coal. The coal, however, has not been found in sufficient quantity to form profitable workings.

The same carboniferous strata appear to the W. of Roxburghshire, and extend along the valley of the river Liddel.

At Canonbie and Langholm, coal is wrought to some extent, but none of the beds exceed 3 feet in thickness.

The Mid-Lothian Coal-Field.—This coal-field occupies the valley of the Esk River, or E. part of Mid-Lothian, extending E. into Haddingtonshire, and terminating in the S. along the base of tho Lammermoor Hills. It forms an area of about 17 miles square, and contains about 225 square miles.

An anticlinal ridge to the S. of Dalkeith separates the basin into two, the one occupying the valley of the Esk River, the other that of the small river Tyne. The series consists of alternating beds of sandstone, shale, coal, ironstone, limestone, and clay, forming an aggregate thickness in the middle part of 6078 feet.

There are from six to seven beds of limestone, the thickness of the beds varying from a few feet to 40 feet, the aggregate thickness being 300 feet. These beds first appear in the lower half of the series, and increase in thickness as they descend. The Burdiehouse limestone, in its absence of all marine fossils, and in the abundance of vegetable remains and minute *Cyperaceæ*, and several species of sauroid and other fishes, indicates a fluviatile and perhaps estuary deposit.

The aggregate thickness of coal amounts to 180 feet. There are between fifty and sixty seams exceeding a foot in thickness, but none more than 13 feet thick; the average thickness is about 3½ feet. The most remarkable seam is the "Great Seam," 13 feet in thickness, accompanied by a mass of coarse-grained reddish sandstone above, and a fine-grained white slaty sandstone below. From 250 to 300 fathoms below this seam is the "North Greens Seam," which yields a cannel coal. The coal-seams almost invariably rest on bands of ironstone and iron nodules, containing a nucleus of organic matter.

The district is traversed by numerous faults, one slip affecting the level of the beds from 400 to 500 feet. Of 109 slips, 94 range between the N. and W., and 7 run due W. The total effect of 78 slips is 35 downthrows to the S. 385 fathoms, and 43 downthrows to the N. 734 fathoms.* The seams are also divided by greenstone dykes of considerable breadth, in the vicinity of which the coal has been carbonised, and the shales and sandstone indurated.

The coal-seams, on an average, thicken towards the N., while the limestone bands, on the contrary, thicken towards the S. Splint, cherry, and cannel coals are raised.

The total amount of available coals in this coal-field has been estimated at 2250 millions of tons.†

Lanarkshire Coal-Field.—This extensive coal-district is a continuation of the great Scottish coal-field to the W., and along the N. slopes of the Pentland Hills, and the more elevated porphyritic mountain-ranges of the Lanarkshire mountains. The workable coal-district extends from Bathgate to Carluke, and hence to Glasgow and Airdrie, occupying the whole central basin of the Clyde.

The old red sandstone forms the base of this carboniferous deposit, and crops out on the S. near Lanark, forming cliffs 400 feet in height, over part of which the river Clyde pours its waters, forming the celebrated water-falls of this district.

Above the old red sandstone, and intermediate between it and the Carboniferous Limestones, are a series of beds of light-grey sandstone, chert, and shales. The true coal-basin consists of alternating beds of limestone, shale, ironstone, sandstone, and coal. Mr Craig ‡ divides this basin into a lower and upper series. The lower series contains three beds of limestone, from 3 to 12 feet in thickness, several bands of valuable ironstone, and fifteen beds of coal. These beds crop out in the S. district of the coal-field, immediately following the old red sandstone, and they again appear to the N. of Glasgow, while the upper beds occupy the centre of the coal-field. These upper beds contain only a few thin bands of limestone, and are composed chiefly of sandstone, with shale, ironstone, and thirty-four seams of coal. About twenty-five of the coal-seams are under 15 inches in thickness, and some seams, with an average thickness of from 3 to 5 feet, are workable. The aggregate thickness of coal is about 37 feet.

The workable seams are:—

1. *The Upper Coal*, only 2 feet thick, and workable at Coatbridge.
2. *The Ell Coal*, 3 or 4 feet thick, forming the Upper Coal of the Glasgow field, wrought at Chapelhall and Airdrie, at Quenter near Hamilton, Dalserf, Motherwell, and Coltness, at which latter place it thickens to from 6 to 14 feet.
3. *The Pyot Shaw Seam*, Monkland, from 3 to 5 feet thick.

---

* PHILLIPS'S *Manual of Geology*.

† MILNE'S "Account of Mid-Lothian Coal-Fields," *Edinburgh Royal Society Transactions*, vol. xiv.

‡ In Prize Essays of Agricultural Society.

4. *The Main Coal*, sometimes connected with the Pyot Shaw, and forming a thickness of 9 feet.
5. *The Hump Coal*, in the vicinity of Glasgow, with a thickness of 2½ feet, but seldom wrought.
6. *The Splint Coal*, from 2 to 4 feet thick, near Glasgow, affords the best quality of household coal.
7. *Shotts Coal*, from 2½ to 4 feet in thickness.
8. *Killorgan Coal*, from 2 to 4 feet thick—very bituminous.
9. *Drumgray Coal*, 1½ feet thick.

The coals are chiefly of the splint, cherry, and cannel varieties. The Boghead and Torbane cannels are the most celebrated of the hydrogenous coals. The latter is situated near Bathgate, and occurs in a bed of from 2 feet to 4 feet in thickness, having 4 feet of shale above, and a bed of common coal below, separated from the other coal by a thin bed of ironstone.

The fossil remains of the lower beds are all of marine origin, while in the upper are found fresh-water shells of the genus *Unio* in abundance. The thickness of this group is calculated at 1320 feet. It abounds in the usual fossil plants of the coal series, and in the dorsal rays, scales, and teeth of *Ganoid* fishes.

There are, in particular, four valuable deposits of ironstone, called "Blackband," in this coal-field, which are very extensively wrought in the district.

1. The Upper Blackband, Palace Craig, Old Monkland.
2. Mushet's Blackband, 16 fathoms below the splint coal, is from 14 to 18 inches thick, and occupies an area of 9 or 10 square miles in the neighbourhood of Airdrie.
3. Crofthead Band lies below the last workable coal-seams, and is about 18 inches thick. It is found also at Langside and Shotts.
4. Shotts Ironstone. This overlies the Shotts Laigh Coal, and consists of a thin band, with rich nodules, having a nucleus of bivalve shells.

The limestones associated with the upper coal-field are seen at Levenseat, where there is an arenaceo-calcareous deposit of 8 feet in thickness. At Gare is a band 3 feet thick, with clay above and below. At New Monkland is a bed 5 feet thick. The same limestone-bands crop out in the vicinity of Glasgow and Port-Dundas. In the lower basin there are three beds of marine limestone—the lowest, which is the best, is wrought at Wilsontown and Carluke in the S. border of the coal-field.

In this lower basin are altogether fifteen beds of coal. The main seam is from 160 to 200 feet below the lowest of the limestones of the upper basin. This seam corresponds in position with that found at Netherwoodson and Temple, to the N.W. of Glasgow, at Calderside, and at Auchinheath and Nethanfoot. This latter yields a cannel or gas coal.

The shales of this lower basin are rich in ironstone. Some of the bands have a thickness of 4 feet. The bands amount to fifteen; that above the third limestone is the richest. There is also a rich ferruginous deposit in connection with the cannel coal, consisting of several bands. The nodules and bands above the main seam are also of superior quality.

The whole coal-basin is traversed by numerous faults and trap veins. When the latter come in contact with the coal, it is charred and altered, as at Airdrie, Barn, and other localities.

A range of trap rises to the surface on the N.E. of the basin of Shotts, and three trap-dykes traverse the district. One is seen crossing the country between Snobe limeworks and High Drumclog; two others on the N. run nearly parallel in a direction from E. to W. These vary in width from 30 to 40 yards, rarely rising above the surface, except at Cameron, where they form elevated ridges of 40 feet in height.

Renfrewshire Coal-Field.—From Port-Glasgow to Ardrossan, along the borders of the river Clyde, old red sandstone strata prevail, having a general dip to the N., and occasionally to the S. and S.E. Its highest elevation inland does not exceed 600 feet. This formation is succeeded by Coal-measures, which are again overlaid and interrupted by a mass of trap, which stretches along the whole N. part of the country, and extends S. into Ayrshire and Lanarkshire. On the N.E. edge of this trap-rock, coal is found in the valleys of the Black Cart Water and the Garnock. Coal and ironstone are wrought at Maxwellton, near Paisley; at Hurlet, coal has been wrought for 300 years. The seam is 5 feet thick, but the coal is much mixed with iron pyrites and alum shale. At Quarrelton are five seams of coal, separated by thin seams of ironstone, the whole having a thickness of 50 or 60 feet. At one place a vertical fault seems to have displaced the strata, and then a horizontal movement has caused the two seams to overlap each other, forming an aggregate thickness of nearly 100 feet of coal. At another place the overlapping strata were separated by a thick bed of sandstone. Limestone crops out at several localities along the edges of the trap-hills, and a fine-grained compact sandstone is abundant.*

Ayrshire Coal-Field.—The Ayrshire deposits form the S.W. portion of the Scotch coal-field, and are separated from the Clyde basin by the trap-hills already mentioned. In the vicinity of Ayr, three thin seams have been wrought, but are now nearly exhausted. Towards the interior of the district the seams thicken, and there is an aggregate of 23 feet of workable coal. At Kilmarnock there is a bed of anthracite 4 feet thick, resting upon sandstone.

---

* MONTGOMERY, *Transactions Highland Society*, vol. vi.

Coal is partially found at Sanquhar, in the Nith. At New Cumnock, seams are wrought near the surface; and at an elevation of 1000 feet above the sea-level are three beds of 9, 11, and 12 feet in thickness. Imbedded in the Twelve-feet Seam is a cannel coal, which supplies the Dumfries gasworks.

All these Ayrshire beds are much disturbed by trap-dykes, and the coal in their vicinity is charred.

Fifeshire Coal-Field.—The N. half of the Scotch coal-district lies chiefly on the N. side of the Firth of Forth and its valleys to the W., occupying considerable portions of Fifeshire, Clackmannan, and Stirling, and extending to the Clyde basin in Dumbartonshire.

The Fifeshire beds commence in the S. valley of the river Eden, and extend across the country, with considerable intervention of greenstone rock, to the shores of the Firth of Forth. The mountain limestone, forming the lowest bed of the series, and resting on the old red sandstone, crops out along the N. edge of the coal-fields at the valleys of Ceres and Cults, and makes its appearance in the S.E. corner of the county at Pittenweem. Very interesting sections of the carboniferous sandstone are seen along this E. sea-coast, exhibiting a succession of waved and anticlinal upheavals. The lower band of limestone is of marine origin; an upper band of a less pure quality exhibits no fossiliferous organisms, with the exception of minute shells, probably of the *Cypres* and *Entomostraceæ.*[*] By frequent intrusions the trap-rocks have been thrown up to the surface. The coal-seams are wrought at many points in the county. In the N. division, coal is wrought at Ceres, where are seventeen beds, having an aggregate thickness of 70 feet at Kettle, Skelpie, and Lathocker; and in the E. and S., at Pittenweem, Elie, Wemyss, Dysart, and Kirkcaldy. Near Kirkcaldy are nine seams, with an aggregate thickness of 25 feet. From Dysart to Wemyss occur twenty beds, with a thickness of 94 feet. The Dysart Main Coal, divided by thin seams of shale into six beds, has an aggregate thickness of 21 feet. Another seam at Wemyss is 9 feet in thickness. The coal here dips under the Firth of Forth, and is wrought at a depth of 900 feet below its surface.. The aggregate thickness of the coal strata here is 1700 feet.

The faults run generally E. and W., and raise the strata to the N. 130, 200, or 600 feet. The coals are mostly splint and cherry. At Methil is found a rich cannel coal.

Dunfermline Coal-Field.—This coal began to be wrought as early as A.D. 1291, probably the first in Scotland; and nearly contemporary with this are two other notices of coal in England—one A.D. 1234, the other 1284. This field extends for nearly 3 miles in length, and contains from four to seven workable seams, having a thickness of from 17 to 26 feet. In the Elgin hills there are twenty-seven seams of coal, with an aggregate thickness of 56 feet. Ironstone is found in this field, and limestone is wrought, especially at Charleston, on the coast, to a great extent. The coals are bituminous, and of the caking kind, somewhat similar to Newcastle coals. The quality is generally superior.

Clackmannan Coal-Field.—This field is bounded on the N. by the Ochil Hills, in an extensive trap-chain, which in this vicinity have yielded, in former times, silver and copper ores, with irons, cobalt, and lead ores. The coal-field at Woodhill rests on old red sandstone, and extends to the coast, a distance of 6 miles. It is divided by steps into three portions. The general dip is to the N.; to the S. it assumes a saddle shape. In a depth of 200 feet are twenty-four beds of coal, with an aggregate thickness of 59 feet.[†] The carboniferous strata extend to Stirling, where they crop out to the N., and then strike W. by Dumbarton, and join the Renfrewshire coal-fields on the W. borders of the Clyde basin.

N. of this great coal district there are no traces of the true carboniferous formations throughout Scotland, though two imperfect beds of coal occur in the Oolite of Brora, Sutherlandshire. The upper seam is 3 feet 8 inches in thickness, the lower 1 foot 4 inches. These were at one time partially wrought, but the quantity of iron pyrites which the coal contained rendered it useless.

This formation, in its mineral beds and organic remains, bears a close resemblance to the Yorkshire Oolite.

Another exception occurs in the Isle of Mull, where a thin seam of coal appears on the shores of Loch Scridden. It is conjectured by the Duke of Argyle to be a prolongation of the Tertiary leaf-beds of Ardtun.[‡]

IRISH COAL-FIELDS.

The carboniferous system occupies two-thirds of the whole area of Ireland.[§] Succeeding the Silurian and Devonian formations which skirt the outer margins of the island, the centre is almost wholly composed of the mountain limestone and lower series of the Coal-measures.

This formation on the W. extends to the coast, composing Donegal, Sligo, and Killalo bays. It then skirts the E. base of the Connemara Mountains, and appears again in Galway, and partially in Dingle Bay. It overlies the old red sandstone in the S. of Cork County, appears at Dungarvan in Waterford County. It is interrupted by the Wicklow range of mountains, but reappears on the coast of Dublin and Drogheda. N. of the trap mountains of Antrim it is again found on the coast.

There appears to exist an intimate relation between the carboniferous beds of Ireland and the corresponding formations of England and Wales. The sections in Cork County exhibit an identity with those of the W. extremity of South Wales, and the beds of the North of Ireland resemble the coeval beds of the North of England.

---

[*] LANDALE, *Essays of Highland Society of Agriculture*, vol. v.

[†] BALD, *Wernerian Transactions*, vol. iii.

[‡] DUKE OF ARGYLE "On the Tertiary Leaf-beds in the Isle of Mull;" *Quar. Jour. Geol. Soc. Lond.*, vol. vii.

[§] Griffith.

The Carboniferous system of Ireland forms an area of 150 miles square, and, according to Griffith, presents the following general section in descending order :—

E.—The Coal Series, but slightly represented.
D.—Millstone Grit.—Occupies a large space around the source of the Shannon, forming the elevated crags of Kulkeagh ; it contains coal, ironstone, and furnace-grits. Thickness, 500 feet.
C.—Great Shale Series of Kulkeagh, containing *Goniatites, Posidoniæ, Orthoceratites, Bellerophons*, &c. Thickness, 600 feet.
B. { *Upper Limestone*, cavernous, with coral bands.
The Calp Series.—Grey and dark limestone, with shale and sandstone ; in some districts only.
Lower Limestone. }
A. { *Carboniferous Shale*, locally rich in *Spirifer, Strophomena*, Fossil fishes, &c.
Yellow sandstone, with shale, and occasionally limestone. }

Each of these lower and upper groups, *A, B*, and *C, D, E*, has an aggregate thickness of 3000 feet. The upper series (*E, D*,) are most conspicuous in the N. about Lough Erne and the sources of the Shannon, about Kilkenny and Castle-Conner, and in the elevated country on each side of the estuary of the Shannon. The true mountain-limestone (*B*) exists to an immense extent in the central districts, while the lower series (*A*) appears in the S. tracts about Cork and Kinsale. At Knock, Upper Kilkenny, the limestone rests in dark shale and yellow and brown sandstone, 150 feet thick : below these are red slates, and red and green argillaceous sandstone, with impressions of *Sphenopteris*.

Near Carrick-on-Suir, Tipperary County, the limestone rests in a thin-bedded yellow sandstone, and green and yellow shales, 150 feet thick, followed by alternations of yellow sandstone and hard red shale, 350 feet thick. Below this succeeds old red sandstone to a depth of 1800 feet. Farther to the W., in the same county, the red shale has a thickness of 900 feet, and the whole series, including the old red sandstone, an aggregate thickness of 4500 feet. To the S. of Cork the dark-grey and green shales alone, with red and green slates and purple sandstones, form an aggregate thickness of 4250 feet. Mr Jukes refers them to the Devonian system, and in their characters they bear a close resemblance to the corresponding strata in the W. of Pembrokeshire, Wales.

The upper Carboniferous series, or true Coal-measures, are but sparingly developed in Ireland ; and there appears to be but little chance of any such rich beds being discovered as those of England. In so far as they prevail, however, they appear similar to the English coal-formation. Thus anthracites, similar to those of South Wales, are found in Leinster and Munster, and bituminous coals in Connaught and Ulster.

Ballycastle Coal-Field.—This field is situated in the N. extremity of Antrim County, and is surrounded and penetrated by trap-rocks—a columnar basalt overlying the coal, and also the chalk, at Fair Head Point. One seam is about 3 feet in thickness, and the quality of the coal is a bituminous splint, but very slaty. Near Gab Cliff colliery the seam is intersected by a trap dyke at right angles, which has charred the coal on each side of it. These collieries were wrought at an earlier period than any others in Ireland, and used to yield annually from 10,000 to 15,000 tons ; but now they are disused.

Tyrone Coal District.—Near Coal Island is a partial deposit of coal, but the beds are now nearly wrought out. At Dungannon nine workable seams, from 3 to 9 feet thick, were worked with moderate success, but are now given up.

In Leitrim, Cavan, and Roscommon counties, surrounding Lochallen, the source of the river Shannon, there are several detached basins of coal, which, however, contain only one bed not exceeding 2 feet in thickness. The shale is rich in ironstone, and the Arigna ironworks here formerly attracted considerable attention, but have been ultimately abandoned.

Kilkenny Coal District.—This district, lying to the W. of the main branch of the Barrow River, is divided by intervening ridges of mountain limestones into four basins. The coal is anthracitic, very much mixed with sulphur. There are several seams, two of which are 3 feet in thickness, two less than 3 feet, and one 4 feet. The upper beds are wrought out ; the lower still remain, but the quality of the coal is so impure as to be unfit for any other purpose than for burning limestone.

The Munster Coal District occupies a considerable portion of the counties of Clare, Limerick, Cork, and Kerry. It contains three beds of anthracite, but none of great thickness. The most valuable portion is found on the N. of the river Blackwater, where several excellent beds of anthracite occur.

Antrim Lignites, or Brown Coal.—This Tertiary deposit occurs abundantly in the N. of Ireland, as well as in some other localities. It underlies the basaltic trap of Antrim, and the beds exhibit a variation in thickness of from 3 to 30 feet in the space of 100 yards. At Lough Neagh these beds attain a thickness of 294 feet, composed of alternations of wood, coal, clay, and sand. It is difficult to ignite, and forms a dull fire, but is, on the whole, superior to peat.

In the year 1854 there were of collieries in operation in Ireland :—

In Leinster field,	5
Tipperary,	5
Munster,	2
Connaught,	5
Tyrone,	2
	19

These produced a total of 148,750 tons of coal.

GENERAL SUMMARY.

On a review of the leading details of the British coal-fields, the following conclusions may be drawn :—

The Coal-measures of England, Scotland, and Ireland are, as regards local position, contiguous to each other, occupying the greater part of the W. and central portion of the British Islands.

The Irish Sea separates Ireland from the West of England ; but the characteristics of the Carboniferous limestone and lower Coal-measures of Ireland bear such a striking conformity to the similar strata of Wales, as to lead to the presumption that they may have been originally continuous. The distance from Whitehaven in Cumberland, where the coal-seams dip into the Irish Sea, is so little, and that little so far connected by traces of the Carboniferous system in the Isle of Man, as to afford additional proofs of the supposed connection of the two opposite shores of Ireland and England. The Scottish coal-fields are only disjoined from those of the North of England by the intrusion, by igneous elevation, of the underlying Silurian and Devonian rocks ; and the same line of basaltic trap appears to be traceable from the coal of Antrim through the Isle of Arran, and North-eastward through the basins of the Clyde and Forth.

From South Wales to the North of Yorkshire, the continuity of the various coal-basins suffers such interruptions only as may be supposed due, in the first instance perhaps, to the original inequalities of the surface previous to the coal deposition ; and in the second place, to the breaks necessarily caused by the upheaval of the surface posterior to the close of the coal era, and to the effects of denudation consequent upon such upheavals.

The mineral and fossiliferous contents of the various basins bear a striking similarity throughout the whole. There exist the same underlying strata of the older Palæozoic series ; the same mountain limestone, with marine organisms, forms the basis of the Coal-measures, the deposits of this limestone varying in thickness according to their localities,—in some places existing in one or two thick beds, in other localities dividing into two, three, or more thinner beds ; some of those upper beds exhibiting fossils indicative of a fresh-water formation.

Above this, the millstone-grit is generally prevalent, or, if absent, it is replaced by beds of red sandstone shales and conglomerates.

In the alternating beds of shales, sandstone, and coal forming the true Coal-measures, certain well-marked strata and seams of coal can be traced as prevailing to a wide extent through several districts in England ; while the same is the case with some of the well-marked Scotch coal-seams.

The fossil vegetable remains are of identical character throughout the whole of the English, Scotch, and Irish basins ; and similar species prevail from the highest to the lowest beds of strata, having a thickness of 6000 feet. *Stigmariæ* and *Lepidodendrons* abound in the sandstones, and large trunks of Coniferous trees are not unfrequent, especially in Scotland ; while impressions of ferns and equisetaceous plants are found in the shales above the coal-seams.

TABLE OF COAL PRODUCE OF GREAT BRITAIN AND IRELAND, 1854 AND 1855.

DISTRICTS.	Tons raised in 1855.	Number of Collieries in 1855.	Persons Employed in 1854.	Price per ton at the Mines in 1854.	Price in London, &c., in 1854.
ENGLAND.					
Northumberland and Durham,	15,431,400	273	38,801	8s. to 11s. 6d.	18s. 9d. to 23s. 10d.
Cumberland,	809,549	23	3,636	8s. 5d.	...
Yorkshire,	7,747,470	333	21,030	5s., 10s., 16s.	20s. in Hull.
Derbyshire,	2,256,000	171	5,434	...	20s.
Nottinghamshire,	809,400	20	3,671	...	...
Warwickshire,	262,000	17	1,414	...	...
Leicestershire,	425,000	11	1,646	...	...
Staffordshire (N. and S.) and Worcestershire,	7,323,000	500	27,869	...	...
Lancashire,	8,950,000	357	28,834	...	...
Cheshire,	755,500	32	2,618	...	...
Shropshire,	1,105,250	56	4,580	...	...
Gloucester, Somerset, Devon,	1,430,620	88	7,501	...	...
NORTH WALES.					
Anglesea, Flintshire, Denbigh,	1,125,000	65	...	...	...
SOUTH WALES.					
Monmouth, Glamorgan, Pembroke, Caermarthen,	8,550,270*	245	...	...	...
SCOTLAND.					
Total of all the coal-producing districts,	7,325,000	403	32,969	...	...
IRELAND.					
Total of all the coal districts,	145,620	19	...	...	...
Grand total,	64,351,079	2613		...	...

* Of which 997,500 were Anthracite.

The three leading divisions of coal—the Anthracitic, the Bituminous, and the Hydrogenous—have their representatives in the various coal-fields,—even the same seams sometimes exhibiting in different places different kinds of coal, and there appearing no fixed order of position of any one particular kind.

The South Wales coal-field abounds in anthracite. The most common kinds of coal are the bituminous, consisting of the splint and cuboidal subdivisions. The *caking* kinds are much more common in England than in Scotland, while the latter district contains the richest hydrogenous or cannel coals.

The Scotch coal-field has been supposed lower in position than the English. Some of the lowest seams alternate with bands of mountain limestone, and the Berwick coal is altogether in this position.

Bands of limestone and shale, with fresh-water bivalves and impressions of plants, exist in the lowest carboniferous beds of Scotland, and are found alternating with marine limestones in the English coal-districts, affording evidence of the alternate elevation and depression of the surface during the formation of the strata.

COAL—ITS COMPOSITION, AND A CLASSIFICATION AND DESCRIPTION OF ITS VARIETIES.

This black hard carbonaceous substance, produced by the vegetation of former geological periods, and regularly imbedded in the stratified crust of the globe, is at once the most interesting to science, and the most valuable to the wants of civilised man, of all the materials imbedded within the earth: it deserves, therefore, a careful investigation of its composition, origin, and uses. Being a very complex substance, or rather a genus of substances of kindred composition, whose ingredients vary much in their proportions, its several varieties must be classified and separately examined or analysed.

Subdividing the whole class of substances we call coal in accordance with their most natural characters, we find them to arrange themselves into the following four principal groups in the order of diminishing carbon and augmenting hydrogen:—*Anthracites, Semi-anthracites; Semi-bituminous coals, and Bituminous coals.*

All the varieties of coal agree in containing, though in very different relative proportions, the following contituents.

Carbon, invariably the most abundant ingredient, and the gases hydrogen, oxygen, and nitrogen, the relative proportions of which are very influential in imparting to certain coals their special qualities. To these (the organic products of vegetation) we must add a variable amount of earthy matter (the ashes of the coal when it is burned), consisting generally of silica, alumina, oxide of iron, and sometimes a little lime, magnesia, potash, &c., and likewise frequently a small amount of sulphur.

It has been pretty clearly ascertained by careful chemical researches, that all coal, even the hardest and driest anthracite, contains more or less of these various substances, and that in the different kinds they not only differ in their relative proportions, but in their condition of chemical union with each other.

In the so-called bituminous varieties of coal, the three principal constituents—carbon, hydrogen, and oxygen—are in chief part at least chemically united into the form of one or more oily inflammable liquids, erroneously called bitumens, recognisable by the microscope in the cells of the coal; and it is clear from certain phenomena, such as the constant evolution of the gases in the free state from the pores of the coal, that another portion of these is locked within the coal in an uncombined but greatly compressed and possibly liquid condition.

Thus it may be stated as a general analysis of all the bituminous coals, that they contain, besides their earthy ingredients—1, Solid carbon; 2, Carbon, hydrogen, oxygen, and nitrogen, chemically combined, but not, as is generally supposed, in the state of bitumen; 3, A residual portion of the hydrogen, oxygen, and nitrogen in the form of free gases, easily disengaged; 4, A small proportion, seldom more than 1 or 2 per cent, of free water mechanically present in the pores and fissures.

The essential difference between the bituminous coals and the anthracites is, not that the latter contain no gases or volatile matter (for they sometimes possess as much as 9 or 10 per cent), but that they are destitute of a perceptible amount of those chemical compounds of the gases and the carbon known as bitumens. In the driest or most thoroughly de-bituminised anthracites, the hydrogen element amounts to about 2 or 3 per cent, and the oxygen and nitrogen together to about as much; and many facts make it highly probable, that while a part of the hydrogen and oxygen are in combination in the form of water, and that some of the hydrogen and nitrogen is in the condition of ammonia, a residual portion of all these three elements is in an insulated state, condensed in the pores of the solid parts of the coal.

In such anthracites, the carbon varies, according to the purity of the coal, from 84 to 93 per cent, while the earthy matter usually ranges from 2 to 12 per cent.

The composition of a coal may be viewed in either of two aspects, and determined by either of two corresponding methods of analysis. In the one we may regard only the proportions of the several ultimate elements, the carbon, hydrogen, oxygen, nitrogen, and earthy substances which enter into it; in the other we may consider it as a union of certain specific combinations of these—namely, of solid carbon or coke, with bitumen, the gases hydrogen, oxygen, and nitrogen, in a free and condensed state, and some of these in the state of water and ammonia, together with the earthy matters. The mere combustion of a bituminous coal effects the successive disengagement of these last-named proximate constituents. Thus, in the first stage of kindling, the greater part of the free gases and of the water is exhaled at a relatively low heat; next, a portion of the bitumen is converted into vapour, with disengagement of a part of its solid carbon, while the temperature is not yet high enough for actual ignition; still later, the rest of the gaseous matter, and a part of the solid carbon, burn off in flame and smoke; and, finally, the residual coke is consumed, leaving only the earthy matter, the ashes.

The distinctive properties of the different kinds of coal are determined mainly, though not altogether, by the relative proportions of solid carbon and volatile matter which they severally contain. Coals are therefore styled bituminous, semi-bituminous, or anthracitic—that is, purely carbonaceous—as they possess respectively a full supply, half a share, or no trace at all of bitumen. When they contain as much as 18 or 20 per cent of volatile combustible matter, they are usually entitled bituminous coals; when less than 18 per cent, and more than 11 or 12 per cent, they claim the name of semi-bituminous; and when a less proportion than 11 or 12 per cent, they are ordinarily designated anthracites.

Of those having more than 18 per cent of bitumen there are two general varieties, the *open-burning* and the *caking* coals. Both of these burn with much flame and smoke, and both swell into a vesicular coke in burning; but the open-burning kind coheres loosely, and permits the air to pass freely between its lumps, while the caking variety agglutinates more closely into a mass, and partially arrests the draught. This property of naturally caking or not caking does not appear to depend, as very many persons suppose, merely on a greater or less abundance of volatile matter; for both the non-caking *splint coal* of England, and the *cannel coal* of that and our own country, rather exceed the Liverpool and other caking coals in their amount of bituminous or more strictly volatile matter. The splint coals average as much as 36 per cent, the cannel coal seldom less than 35, and frequently as much as 45 per cent, while the caking coals rarely exceed 32 or 34 per cent of total volatile ingredients.

The semi-bituminous coals also soften and swell into compact coke, but do not agglutinate at all, or only slightly; they are therefore equally eligible with the non-caking bituminous varieties for certain purposes of combustion; while, as we shall presently see, they are preferable to them in heating power, in proportion to the greater weight of solid carbon they contain.

The anthracites neither soften and swell or vesiculate while burning, nor do they emit any smoke, strictly so called. Those varieties, however, which contain from about 7 to 10 per cent of volatile matter, evolve in the early stages of combustion a visible amount of yellow carbonaceous flame, the product of the easily-ignitible carburetted hydrogen gas, which is most probably present in the free state in the cells and crevices of the coal, and not derived by decomposition from any bituminous matters. These are the free-burning easily-kindled anthracites. They are, for the most part, fissured by numerous fine clefts or joints, by virtue of which, and of the expansible gases these enclose, the lumps spontaneously subdivide on the fire, in a greater or less degree, into small cuboidal fragments. These coals constitute, I conceive, a distinct variety, being, when of equal purity in regard to earthy matters, intermediate in colour, lustre, and specific gravity, between the semi-bituminous kinds on the one side, and the dry hard anthracites on the other; and as they derive, from their peculiar mechanical structure and special chemical composition, definite and valuable qualities for several of the leading uses to which fuel is applied, I deem it convenient and proper to give them a separate designation: I shall, therefore, always allude to these as the *semi-anthracites.*

The true or hard anthracites constituting the first division of this class of coals contain, when free from mechanically-imbibed water, from 2 to 5 or 6 per cent of volatile matter, consisting of minute quantities of the atmospheric gases, and hydrogen, carburetted hydrogen, and also 1 or 2 per cent of water very tenaciously retained.

These anthracites, when pure, and not dislocated from the excessive pressure which attended the uptilting of the strata, have their fine intersecting joints or clefts far asunder, and nearly perpendicular to the grain of the coal, and they break with a semi-conchoidal fracture. They are harder and denser than any of the other coals, and by their firmer cohesion, their resistance to subdivision on the fire, and their destitution of inflammable gaseous matter, are the most difficult of all coals to kindle, and require the highest temperature for the maintenance of their combustion. The very hardest kinds yield an almost semi-metallic sound when struck, and in their slightly-bluish tint and their faintly plumbaginous lustre, they suggest plainly their affinity in composition to true graphite or black-lead. In these and all their other characteristics the genuine anthracites give evidence of their having been exposed since their deposition to a far greater intensity of terrestrial heat than any of the other kinds of coal. Anthracite is unquestionably the metamorphic form of ordinary bituminous coal, and has derived its peculiar composition of a nearly pure carbon, and its other important qualities, from the slow expulsion, under great pressure, of the volatile parts of the coal, through the action of a high distilling temperature pervading the strata enclosing it.

To a somewhat less elevated or prolonged heat in the earth's crust, we are equally well entitled, by all geological testimony, to ascribe the more imperfect removal of the gaseous elements in the instance of the semi-anthracites; and to various yet feebler degrees of heating, we are manifestly compelled to assign all the corresponding grades of the bituminous character met with in the semi-bituminous and the drier bituminous coals.

These general introductory views of the composition and structure of the several leading species of coals, will be seen to possess much practical importance in suggesting the proper uses and adaptations of the respective varieties, and the conditions under which each species should be burned to insure the highest economy of their heating power. Each of the four dominant kinds of coal described has been found by experiment to subserve, better than the rest, some appropriate end or ends in the multifarious operations of the arts; but the practical man is continually deceived in his calculation of the economy of his fuel through inattention to the chemical laws of combustion, and through incorrect conceptions of the true nature of the special variety of fuel he is using. Without such knowledge, the whole economic problem of his coal and his furnaces is but guess-work the moment he essays a new variety, or introduces any material alteration in his mode of burning even a familiar species.

Directed by these preliminary views of the composition and qualities of the several species of coal, I propose to classify and describe them somewhat more technically, upon a combined basis of their chemical and structural characters, or in accordance with their composition and manner of burning.

Retaining the above convenient classification of coals, into the four varieties of Anthracites, Semi-anthracites, Semi-bituminous, and Bituminous Coals, which has already crept extensively into use since first presented by me, and is constantly employed in this work, I propose to introduce here a more extensive one, simply modifying this grouping, and recognising certain varieties or sub-varieties not yet designated.

Looking at the essential differences in the several kinds of coal depending on their gradations in composition, it will appear, I think, that the soundest general classification is into three great varieties and groups—*the Anthracites, Bituminous Coals,* and *Hydrogenous Coals,* arranged in the order of diminishing carbon and augmenting hydrogen. At the one end of this scale we have the anthracites; natural cokes, yielding almost no flame and no smoke; coals with the maximum of solid carbon, and a minimum of the gaseous elements. At the other end of the scale, the very hydrogenous coals, almost destitute of true coke, and convertible almost wholly into flame with smoke; coals with the least proportion of fixed carbon, and the greatest amount of hydrogen gas; while, intermediate between these extremes, are the common bituminous coals, containing a medium share both of solid carbon and of the gaseous elements—capable of producing a fair amount of coke, and a moderate per-centage of the inflammable or hydrogenous gases. This grouping will be found, I think, at once scientifically correct and expressive, and practically applicable and useful.

But these three classes of coals demand, as we have already partly seen, a subdivision into special varieties—the *Anthracites* being properly separable into *Hard Anthracites* and *Semi-anthracites;* the *Bituminous Coals* into dry or *Semi-bituminous,* and *fat or true Bituminous Coals;* and the *Hydrogenous* into *Cannel* and the richest *Gas Coals.*

To this point the classification mainly recognises the relative proportions of fixed carbon to gaseous matter, especially hydrogen; but a yet further sub-grouping of some at least of these varieties is called for, to express not so much the lesser differences of composition, as the conditions of *constitution* or *chemical structure,* resulting in peculiarities of their modes of decomposing under heat and burning. This gives us a partial classification of certain coals, which is *transverse,* so to speak, to the main linear one of a simple gradation in the quantities of carbon and hydrogen. Guided to these differences among the bituminous coals by this second clue, we shall find the true or fat bituminous group to include three well-marked sub-varieties, already recognised by their distinctive properties, and known under familiar names. These are the *caking coals,* the *cherry coals,* and the *splint coals* of the English miners, and of commerce. In the same manner, looking to the behaviour of the leading kinds of the very hydrogenous coals, as well as to the differences in the proportions of hydrogen in them, we shall find these to include at least three very unlike varieties of the rich gas-making sorts, severally represented by the ordinary or typical cannel coals, by the Torbanehill gas-coal, and by Albert coal of New Brunswick. It is not easy to find suitable familiar designations for the two last named of these three hydrogenous coals; but I think the term hydrogenous shale or clay-coal is a fit enough name for the Torbanehill variety; while the lustrous, fusible, and exceedingly pure Albert coal, may claim appropriately the title which has been sometimes applied to it, of the *Asphaltic* coal, without signifying that it contains or consists of either real asphaltum or solid bitumen.

Applying to the group of semi-bituminous coals a similar discrimination, we may discern even among them the two sub-varieties of cherry and splint coals, each, however, having a less share of volatile matter than in the corresponding true cherry and splint coals of the fully-bituminous group.

Indeed, we might properly enough extend the distinctions of splendent, cubical, and dull splintery or slaty coals to the two leading qualities of anthracite, only that it would mislead to apply to any variety of this the restricted name of Cherry coal.

That peculiar species of coal which is so distinctive in the cannel coals,—that dull greyish-black variety, which evidently owes its want of lustre and of fusibility, not to the presence of earthy matter, but to some essential circumstance in its composition—possibly an abundance of free carbon, some special condition attending its origin, possibly a prolonged masceration of the vegetable matters before their final entombment—certainly mingles with the other, or glance variety, in greater or less proportion, in all the great classes of coals, from the most hydrogenous to the anthracites. Both kinds have been subjected together to various degrees of distillation of their more volatile constituents, perhaps to dissimilar extents in the different groups, anthracites, bituminous, and hydrogenous; and therefore it is that we see the dull and the bright varieties so intimately alternating in all of these classes, even where we cannot impute the dull laminæ to any excess of earthy matter.

Adopting the above distinctions, we may accordingly arrange all the best-known descriptions of coal upon the following scheme or classification :—

- ANTHRACITES, ...
  - Hard Anthracites.
  - Semi or Gaseous Anthracites.
- COMMON BITUMINOUS COALS,
  - Semi-bituminous Coals,
    - Semi-bituminous Cherry Coal, and
    - Semi-bituminous Splint Coal.
  - Bituminous Coals,
    - Caking Coal.
    - Cherry Coal.
    - Splint Coal.
- HYDROGENOUS OR GAS COALS,
  - Cannel Coals.
  - Hydrogenous Shaly Coal (Torbanchill, &c.)
  - Asphaltic Coal (Albert Mine).

Having taken this brief general survey of the whole class of coals, and developed the classification adopted in this work, we may now look more closely at the physical and chemical characteristics of the several species or kinds. In doing this we will follow the order in which they are presented in the foregoing Table, beginning with the most carbonaceous coals, and ending with the most hydrogenous.

THE ANTHRACITE COALS.

The term *Anthracite* may be strictly applied to all those dry or non-bituminous coals, which, possessing from 2 to about 10 per cent of gaseous matter, do not swell or intumesce when burned ; or which, in other words, give off the small amount of volatile constituents they contain without coking. All of these coals enclose, as already said, a minute quantity of the atmospheric gases and hydrogen, with a little water firmly retained ; and some of them contain, besides, a notable amount of the combustible gases, probably in a free condition.

The *carbon*, their chief and most important constituent, prevails in all proportions, from 94 per cent in the very purest and least gaseous anthracites, to any lower ratio, until, from excess of earthy matter, the substance can no longer be called nor used as coal, but deserves the name of carbonaceous slate. The earthy matter is seldom less than 3 per cent in the purest varieties, and more than 10 per cent is incompatible with excellence as a fuel.

THE TRUE OR DRY ANTHRACITE.

This the first species in the Table, is characterised by its semi-conchoidal fracture, the fewness and squareness of its joints or clefts, great relative hardness and density, its high specific gravity, ranging from 1.40 to 1.80, iron black or plumbaginous colour, and its semi-metallic and splendent lustre. It burns without any smoke or yellow flame, but with a weak blue flame—that of carbonic oxide when newly kindled—and with a thin transparent pinkish and intensely-hot flame when in full combustion. True anthracite, when pure, is slow to ignite, conducts heat very badly, burns at a very high temperature, radiates an intense warmth, and is difficult to quench. Generating almost no water during its combustion, it powerfully desiccates the atmosphere of an apartment in which it is burning. Like the diamond, it is a perfect conductor of electricity, but acquires negative electricity when insulated, and subjected to friction. It is sometimes described as a mineral, but is more truly a rock, or mechanical solid aggregate of earthy and organic matter stratified, and therefore neither amorphous nor crystalline.

It consists, when pure, of—

Carbon, . . .	from 94 to 90 per cent.	Water, . . .	from 1 to 2 per cent.
Hydrogen, ...	1 „ 3 „	Ashes, ...	3 „ 4 „
Oxygen and Nitrogen, . .	1 „ 3 „	...	... ...

The constituents which vary most are of course the carbon and earthy matter ; and in the impure sorts, the first of these is frequently as low in amount as 75 per cent, the ash being then as much as 20 per cent. In Pennsylvania, such earthy or slaty coal is technically called by the miners *bone coal*. One variety of impure anthracite is where all the laminæ are earthy, and dull in lustre ; another is where the dull or slaty leaves alternate intimately with the splendent or pure anthracite, but in such excess as to render the mixed mass impure.

One of the synonyms of anthracite is glance-coal, from its brilliant lustre ; another is blind-coal, from its burning without bright flame ; while that of Wales and Devonshire is locally called *culm*. It is familiarly called hard coal, in contradistinction to the softer bituminous coals in New England and other parts of the United States, where it comes into contact with the fuels of the other class.

Hard anthracite, from its great richness in carbon and its density, stands at the head of all coal for its heat-generating power, if adequately supplied with air. It is therefore particularly valuable for producing steam, where power only, and not speed, is wanted; and it is the most economic of all fuels—weight for weight—for smelting and melting iron and the other metals. For domestic uses, it is best employed, where the climate is cold, as an auxiliary for warming air; but it is difficult to control, and it emits too scorching and intense and dry a heat to make it a pleasant or wholesome fuel, burned in the open grate. Skilfully employed, it is admirably adapted for cooking, but it requires special appliances and more skill than other fuel for an economical application to this purpose. It is extensively applied to all the purposes here mentioned in the Middle Atlantic and Eastern States, where it is abundant and cheap.

The superior density of hard anthracite over every other kind of coal, by lessening the room demanded for stowage, gives it a decided preference in this respect as a fuel for ocean steamers, where the trips are very long or the tonnage precious; and in these cases even the fracture of the coal, by influencing the closeness of its stowing, is a consideration.

The *conchoidal fracture* in dry or hard anthracite seems to depend as much on its homogeneity or evenness of composition and structure, as on its purity or freedom from slaty matter; for some rather earthy varieties, in which the ashy constituents are diffused throughout the coal, exhibit this in a higher degree than other more carbonaceous kinds, in which the pure coal and the slaty are distinctly laminated. Hence this fracture is not so true a test as is generally supposed of the purity of the fuel. Every bed of tolerably pure hard anthracite displays at its outcrop, and to a small depth below, a prevalence of the ovoidal and globular shapes in its loose and weathered lumps. This is a consequence of a tendency to the conchoidal fracture, and of that exfoliation or peeling off at the corners and edges which results from alternate wetting and drying, and which belongs to nearly all homogeneous earthy aggregates when similarly exposed to the weather. Where the coal is finely laminated and uniform in texture, the form resulting from long weathering is ovoidal, or that of an egg more or less flattened; but where the mass is very homogeneous, and cubical in its joints, the shape approaches near to the globular.

We may distinguish two kinds of joints or planes of separation in almost every bed of hard anthracite—viz. structural joints, or clefts symmetrically disposed, and generally pretty nearly at right angles to the planes of bedding or lamination of the coal, and also at right angles to each other; and mechanical joints, or planes of fracture, resulting from compression during unequal tension of the strata. The second of these classes, the mechanical joints, numerous in all strata which have been much moved or uptilted, abound more in the highly-inclined and faulty beds than in the more horizontal ones, and more in very hard and highly-metamorphic anthracites than in the softer semi-anthracites and bituminous coals; while, on the other hand, the true structural joints, or those arising from evenly-diffused shrinkage and from the molecular forces excited by the heat which dislodged the bituminous matter, are most numerous and closely disposed in the softer or semi-anthracites. An interval of from half an inch to several inches usually separates these *cleats*, as they are called by miners, which cross the lamination of the coal at right angles, and are coincident approximately with the line of the dip. These are the smoothest and best-marked of the two sets of joints. The others, which are also perpendicular to the stratification, but are approximately at right angles to the dip, or parallel with the strike of the beds, are generally farther asunder, and not so clean and smooth. Both systems of cracks, but especially the cross-cleats, are very frequently filled with a white substance—a nearly pure form of silica—which, we may conceive, has been either segregated from out the substance of the coal itself, where some original silica no doubt exists as a secretion from the reed-like vegetation, or introduced mechanically into the clefts of the shrinking coal in a vaporous state, sublimated very probably by the hot steam and volcanic gases which everything indicates to have been the main agents in the de-bituminisation or metamorphosis of the coal-beds. One form of these cleats, both with and without this white coating, is where the clefts are excessively slender, or not wider than the thickness of fine paper, and of proportionately small areas, losing themselves in the coal. When these minute fissures are numerous, the fresh fracture of the coal is marked with small roundish or oval eyes, whence I have proposed for this variety the title of *Bird's-eye coal*. Frequently these small disc-like figures, which exhibit a curling or flattened conchoidal fracture, such as we frequently see in badly-annealed glass, and which suggests that they have been caused by contraction or shrinkage of the coal, are filled with the white flaky silica, each fissure, when small and undulated, enclosing a delicate round or oval scale of it like a white spangle. An anthracite in which this feature much abounds, however pure it may be in other respects, or rich in carbon, is called technically by our miners *rough coal*. For certain uses, especially for domestic consumption, its value is sensibly impaired by even the small amount of incombustible mineral matter it contains in its clefts; for this, though minute in quantity, has a tendency to exclude the air from contact with the coal when burning, which it therefore causes to kindle, and consume too slowly. Some of the rough Bird's-eye coal does not crumble down or fall asunder by its fissures, as much cleaty coal is apt to do; and therefore, where lumpy coal is preferred, as it is by some of the smelters of iron, its toughness is a recommendation. The most highly metamorphosed coal of the United States—that of Rhode Island—exhibits this mineral matter in its clefts in great abundance; and partly from this cause, and partly, perhaps, from its great density, it is the most difficult of all the anthracite coals to ignite, or to maintain in active combustion when employed alone, or without a strong current of air.

Occasionally in the anthracite coal-beds of Pennsylvania we meet with minutely-diffused silicious sand in coal otherwise pure; indeed, this so-called *sandy coal*, the best instances of which are to be seen in the Dauphin Basin, is usually not a slaty or argillaceous variety.

Sulphuret of Iron.—All coals, and all carbonaceous slates and shales, contain, it is well known, more or less sulphuret of iron, generally minutely diffused in scarcely-discernible crystals, but sometimes in visible and even large crystalline aggregates, or in flakes lining the cracks and joints of the stratum. Anthracite, on the whole, would seem to contain a rather larger proportion of sulphur in this combination than those coals which retain their volatile constituents, but the cleaty varieties are not necessarily the most charged with it. The sulphuret of iron would seem to abound most in the slaty laminæ of the anthracite—though small specks of it may be often detected in the coal itself, with help especially of a magnifier. Even when it is not more abundant in dry anthracite than in the bituminous coals, it causes the air from this species to be more deleterious than from those gaseous fuels, in consequence of the conversion of nearly all of it into corrosive sulphurous acid gas, while in the bituminous coals the hydrogen and other gases serve as a partial counteraction, by forming with it other less injurious compounds. Ventilation of apartments in which anthracite is burned is therefore even more indispensable than where the fuel is an *equally* sulphurous soft coal.

Mineral Charcoal, as it is sometimes called, but which is a true vegetable production, as its structure discloses, but preserved in the fossil state, is equally a constituent of the anthracite as of the bituminous coal. It occurs in little layers, parting the solid seams which make up the thicker beds of the anthracite, in all thicknesses from that of a shilling to several inches, though it is seldom met with more than half an inch thick. Its presence in the non-metamorphic coals as abundantly as in the anthracites, is one of several circumstances connected with it, going to prove conclusively that it is an original product formed at the time of the deposition or first conversion of the vegetable elements of the coal, and not an after-result of any partial heating or combustion of the coal by subterranean fires, as many persons imperfectly instructed in the chemistry of geology have imagined. This charcoal, produced possibly in contact with the atmosphere, and not under water, on the surface of the ancient coal-forming bogs, and not within them, has escaped the masceration which converted the rest of the vegetation to a soft pulpy disorganised mass, already freed from the gases associated with it in the tissues of the plants, and reduced to the elemental and unalterable condition of pure carbon, but by a change so gradual and soft as to have retained its original organic structure, has undergone no after-alteration whatever, when the more complex soft coaly matter enclosing it was heated and decomposed, and had its volatile and bituminous constituents distilled and driven away.

SEMI-ANTHRACITE, OR SOFT GASEOUS ANTHRACITE.

This variety of the anthracite class of coals is distinguished from dry or hard anthracite by possessing a black or less plumbaginous hue, less hardness, less density, and a less metallic lustre and sound, and by containing a perceptibly greater amount of gaseous ingredients. The conchoidal or "glass-bottle fracture," as it is sometimes familiarly named, is not so predominant, while the fine transverse clefts or cleats are closer and more numerous, their average distance not exceeding a third or a half of an inch. Adopting 1.50 as the mean specific gravity of the hard anthracites of Pennsylvania, that of the semi-anthracites of the same region is expressed by 1.40, which is the density of the pure Welsh anthracites. The semi-anthracitic qualities are restricted, with few exceptions, to those coals which possess from 6 to 10 or 11 per cent of total volatile constituents, or on an average from 7 to 8 per cent of volatile combustible matter. In consequence of this element, part of which at least resides probably in a free or gaseous state in the cells and clefts of the coal, this variety kindles more promptly, and, when sufficiently supplied with air, burns more rapidly, than the hard anthracite. When first ignited, it emits a small amount of yellow flame, distinctive of the burning of the carburetted hydrogen gases; after which it gives off only the lambent, thin, but very hot flame of true anthracite. The semi-anthracites crumble up or divide into small angular fragments more readily on the fire than less-jointed hard anthracites; and this quality, inconvenient in some cases where the draught is feeble, by causing too dull a fire, is a real excellence wherever the draught can be regulated, and a sufficiently energetic one secured; for if only the additional influx of air is sufficient to overcome the increased friction consequent upon the increase of surface and multiplication of edges arising from the smallness of the lumps, these coals are found to engender almost as high a heat as the anthracites, while they can be made to burn both faster and more steadily. Their absolute efficiency for equal weights is perhaps a little less, proportioned to their smaller total quantity of carbon; but their actual efficiency in equal times is as great, or even greater, than that of the hard anthracites, by virtue of their superior quickness of consumption.

Good semi-anthracites of the Western portions of the Southern and middle anthracite coal-fields of Pennsylvania, display an average composition as follows:—

Fixed carbon, ...	84.00 per cent	Water dispelled at 312°, . .	2.50 per cent.
Inflammable gases, . . .	7.50 "	Earthy matter, . . .	6.00 "

Precisely the same inequalities in purity, or in the proportion of carbon to earthy matter, exist in this class as in the hard anthracites, both kinds having about the same minimum of sedimentary foreign matter.

The especial excellence of the semi-bituminous coals consists in the readiness with which they burn after being kindled, combined with an absolute heating power almost as great as that of the dry anthracites. When once the proper appliances are used for giving them their fullest efficacy, these coals will probably take the very highest rank among the fuels best adapted for the economical generation of steam. Their successful application to the smelting of iron in high furnaces—a result not yet achieved—must depend altogether on the adequacy of the weight of blast employed. They evidently present more friction to the blast than the large-lump anthracites, for a reason already assigned; but this need be no hindrance to their economic application, since in all well-constructed anthracite iron-furnaces there is a larger surplus of heat engendered—a far larger—than is equivalent to any additional amount of power demanded to overcome increased assistance from a partially-friable fuel.

Under every mode of burning coal for ordinary domestic purposes, excepting perhaps that of the common open grate, having a languid chimney-draught, the semi-anthracite proves to be an admirably convenient and profitable fuel. It is more easily checked and regulated than hard anthracite, while it yields, when required, as hot a fire.

It is interesting to observe the several manifestations of a lower degree of metamorphism in the semi-anthracite, compared with the true anthracites. Thus, while the latter resemble jaspery slates in the extent to which a semi-crystalline cohesive force, causing conchoidal fracture, predominates over the force of mere sedimentary aggregation, the former are more nearly equivalent to that stage of alteration in clay-slate which presents an abundance of jointage, with a moderate but not excessive induration. Again, the semi-anthracites are less dense and compact, and even in some instances are minutely and partially *vesicular*—in the condition, that is to say, of a true *coke*, in which the cells have not been altogether obliterated from excess of heating and dissipation of the volatile matter, as they have been in the anthracites; more acted on by subterranean heat than the bituminous coals, which seem not to have had their temperature raised to the point of chemical decomposition, and extrication of their gaseous matter, or to the point of *coking;* and less excessively baked than the dry anthracites, in which this decomposition was total. These and the semi-bituminous coals, the two varieties of semi-metamorphic coal, display just those intermediate grades of organic change in which we can best discern the proofs and the modes of the metamorphism.

THE BITUMINOUS COALS.

Next in the order of classification are the Common Bituminous Coals, divided into the semi-bituminous and full-bituminous varieties, which are again subdivided, as shown in the Table, into Caking, Cherry, and Splint coals. This class of coals is separated from the anthracites on the one side, and from the hydrogenous coals on the other, by containing or yielding both coke and the combustible gases, while the anthracites consist almost exclusively of fixed carbon or coke, and the hydrogenous produce scarcely any coke, but only the inflammable hydro-carbons. Perhaps, in the generic sense, all coals, except the anthracites, should come under the denomination of bituminous coals, using this term in its ordinary loose acceptation; but it is not precise enough for the purposes of definition, unless restricted as here proposed. In strict chemical language, it is doubtful if any coals are truly bituminous, or contain the substance bitumen (unless perhaps occasionally in minute quantity), in the free or ready-formed condition; they only abound in the elementary principles of bitumen, and yield products very analogous to those which it furnishes when similarly distilled and burned. Perhaps the most generally intelligible designation for this special group of coals is that I have chosen of "*Common Bituminous Coal.*" A not inappropriate familiar name would be *coke coal*, distinguishing it from the gasless anthracites and the cokeless gas coals.

In external properties, the common bituminous coals range in colour from a pitch black to a dark brown; their lustre is vitreous, resinous, or, in the more fibrous varieties, silky; their structure is compact or cuboidal, slaty, columnar, and even fibrous; and their fracture, irrespective of structural joints and cleavage, is conchoidal, and often flat and rectangular, and sometimes fibrous. It is distinctive of these coals to burn with more or less of yellow bituminous flame and smoke, and to emit, when burning, a bituminous odour. In *proximate composition*—namely in fixed carbon or coke, volatile matter or combustible gases, and earthy sedimentary residue or ashes—they may be regarded as ranging between the following general limits:—

Fixed carbon, . .	from 52 to 84 per cent.	Earthy matter, . .	from 2 to 20 per cent.
Volatile matter, .	„ 12 „ 48 „	Sulphur, . . .	„ 1 „ 3 „

Dried at a temperature of 212° F., they yield of water from 1 to 3 or 4 per cent.

The proportion of earthy matter is of course too variable to have a maximum limit affixed to it, as all the kinds of coal may by impurities graduate into carbonaceous shales.

In *ultimate composition*, the coals of this class may be recorded as ranging approximately nearly thus:—

Carbon, ...	75 to 80 per cent.	Oxygen, ...	4 to 10 per cent.
Hydrogen, ...	5 „ 6 „	Sulphur, ...	0.4 „ 3 „
Nitrogen, ...	1 „ 2 „	Ash, ...	3 „ 10 „

BITUMINOUS COALS.

Caking Coal.—This very common variety of bituminous coal, when put in the fire, breaks into a number of fragments; as it becomes more heated, these fragments melt, and run into a mass or *cake*, which, as the heat increases, emits from its interior jets of inflammable gas, leaving a very porous coke or cinder.

The colour of this coal is a velvet black, streaked with greyish black; the lustre shining and resinous. The longitudinal fracture is straight and slaty; the cross-fracture partly small-grained and uneven when the lustre is dull and glistening, and small conchoidal when the lustre is brighter. It is soft and easily broken, the fragments assuming a cubical shape. It readily soils the fingers, and makes a distinct streak on paper. Specific gravity, 1.269.

This is one of the most commonly used English coals. It readily ignites, and burns with a lively yellow flame. It is lasting, and gives out a steady heat; but from its property of fusing into cakes or masses, it requires to be frequently stirred, so as to admit the air into the interior of the masses. The best qualities contain 76 per cent carbon, 5 hydrogen, and leave $1\frac{1}{2}$ ash.

Cherry Coal.—This coal in appearance nearly resembles caking coal. The colour is a velvet black, with an admixture of grey; the lustre is resinous, sometimes dull, in other cases shining. The longitudinal fracture is slaty, the plates having a varying lustre; its cross-fracture is usually flat conchoidal. It readily splits into rectangular fragments, approaching a cubical form, and is so frangible as to break down into a great amount of waste. When exposed to heat, it does not run into cakes, but readily ignites, and burns with a clear yellow flame, giving out much heat, but consumes faster than either caking or splint coal. It in general contains more carbon and hydrogen than the caking coal, and leaves about 10 per cent of ash. It is a very abundant coal, and is extensively used as an article of fuel. It is called *cherry* by the miners, from its lustre and beauty. Specific gravity, 1.265.

Splint Coal—Slate Coal.—The colour is black, with a shade of brown; lustre resinous, dull, glistening. The longitudinal fracture is imperfect, curved, slaty; the cross-fracture fine-grained, uneven, and splintery. In mass it is not easily broken. Between the splint coal, thin layers of cherry coal frequently intervene, which are distinguished by their superior lustre. Splint coal requires more heat to ignite it than either caking or cherry coal; but it then burns with a durable, steady heat. The best qualities leave about 9 per cent of ash, but inferior kinds a much greater amount. Splint coal is of various qualities, and is extensively used for economical purposes. Specific gravity, 1.290.

HYDROGENOUS COAL.

The varieties grouped under this head, from the amount of combustible matter which they contain, and the readiness with which this is given off in combustion, have by the miners obtained the name of *cannel* or candle coal, pieces of the coal, when ignited, giving out a flame like that of a candle. When a large piece of this coal is put in the fire, it splits up into fragments with a crackling noise, somewhat like the chattering of a parrot; hence also the provincial name of *parrot* coals.

The general aspect of the hydrogenous coals is that of a dark compact mass of a black, brown, or greyish colour; a resinous lustre, sometimes dull, sometimes glistening. The fracture is sometimes slaty, or flat conchoidal. The surface is softish, may be easily marked with a sharp-edged instrument, and in many of the varieties (especially in *jet*) takes a good polish. They break up into fragments of various forms,—sometimes approaching the cuboidal, sometimes flat wedge-shaped, and in others quite irregular. Specific gravity, 1.272.

These coals are distinguished by the amount of volatile combustible matter, which varies in the different qualities from 30 to 70 per cent. In a common fire they burn away quickly, with much flame and smoke, but impart little heat. The richest hydrogenous coals are those of Lesmahago, Capeldrac, Methil, and Torbanehill in Scotland.

The Torbanehill coal, when treated in a particular mode of distillation, yields also a peculiar oil, called paraffine.

The Torbanehill coal-seam is from 2 to 4 feet in thickness, and lies above a seam of common splint-coal, with a bed of ironstone intervening.

Most of the varieties of cannel coals are more or less employed for the manufacture of gas, those in which hydrogen bears a high proportion to oxygen being the best. Those also which are free from sulphur or iron-pyrites are also preferred.

From the Torbanehill coal 14,000 cubic feet is obtained per ton, occasionally 16,000 to 18,000 feet; the Wigan yields 11,500 cubic feet.

The best Wigan cannel yields 10 per cent of the heavy carburetted hydrogen, a highly-illuminating gas; the Torbanehill yields 20 per cent of the same gas, and occasionally even more.

The best gas-yielding coals yield the best coke.

The minimum yield of gas from cannel coals is 9000 cubic feet per ton.

CAUSES OF THE GRADATIONS IN COAL.

Corresponding with the progressive augmentation N.W. of bituminous matter in the coals of the whole Appalachian chain, is a gradual but perceptible increase of volatile constituents in the anthracites of Pennsylvania, within the more restricted limits which they occupy. In this part of the chain, however, the direction of the maximum rate of softening of the coal, and introduction of volatile and bituminous matters, would seem to be nearly due W., or perhaps more exactly towards the W.N.W. The gradation will be found to be not absolutely regular, but to fluctuate within quite narrow extremes, as might be anticipated from the very obvious relation of the degree of de-bituminisation, to the varying degrees of heat and disturbance which have locally affected the strata. Even in the same locality, the closely-adjacent beds will differ by 2 or 3 per cent in their quantity of volatile matter.

Surveying the whole anthracite coal-field, and comparing the coals in their average composition, we find that from the Lehigh and the Lackawanna streams, W. to Black Spring Gap in Dauphin, and to Shamokin, their usual proportion of total volatile matter is about 5 per cent. Of this, generally one and a half per cent is moisture, and the other 3 or 4 per cent hydrogen, oxygen, nitrogen, and other gases. The coal between these limits may be all classed under the one denomination of genuine or hard anthracite. But for a few miles from the meridian mentioned, extending in the Southern Basin from Black Spring Gap to near Rausch Gap of Stony Creek, and in the Wiconisco Basin from Klinger's Gap W., and in the Shamokin Basin from a little W. of Shamokin Gap to the extreme W. end of that basin, the coals show a gradual but decided increase in their quantity of volatile matter, with a progressive departure from the characteristic hardness, lustre, and colour of the true anthracites. These are the limits of what I have termed the *semi-anthracites*, which are nowhere so well characterised, so well developed, and so accessible, as in the Shamokin Basin, for 2 or 3 miles both E. and W. of Zerbe's Gap, near Trevorton. Between the meridians now defined, the average amount of volatile matter in the coal is about 9 per cent, some 6 or 7 per cent of which is combustible gaseous matter, and the rest is moisture and non-combustible gases. As already mentioned, these gaseous anthracites are traversed by more numerous fissures than the harder kinds farther E., and, as a consequence, their mode of burning is essentially different. A very regular gradation in the increasing frequency of the little joints alluded to, is perceptible in tracing these coals from where they merge into the compact anthracites on the one side, to where they pass into the semi-bituminous coals on the other. From a third to a half of an inch is the prevailing distance which separates the cracks in the genuine semi-anthracites of Zerbe's Gap, those of the W. end of the Wiconisco Basin, and those of the E. part of the Dauphin Basin; and it is an interesting fact, that they are almost absolutely parallel with each other, and constitute but one set or system of joints, whereas the softer semi-bituminous coals are traversed perpendicularly to the lamination of the coal by *two* or more sets of still more closely adjacent fissures, by which their laminæ are throughout extensive districts rendered minutely *columnar*. The economic considerations connected with the respective effects of these modes of fissuring, will be discussed in another section of this paper.

From about 2 miles E. of Yellow Spring Gap of Stony Creek, W. along the Dauphin Basin to its termination within 10 miles of the Susquehanna, the proportion of bitumen in the coal increases from an average of 10 per cent to an average of 14 or 15 per cent, fluctuating in the different beds from 8 to 12 per cent at the Eastern end of this belt, and from 13 to 14 at the Western; this range includes, then, the drier class of semi-bituminous coals, and towards its E. limit some true semi-anthracites. And the same seams which at Yellow Spring Gap are dry semi-bituminous coals, are all of them semi-anthracites at Rausch Gap, only 4½ miles farther E. Into the question of the sources of this difference in the amount of volatile matter remaining in different closely-contiguous coals of any group, either semi-bituminous or bituminous, I shall not here enter, as this is not a point of any obvious practical moment.

By the foregoing description of the progress of the gradation in bituminous matter, it appears that in the Dauphin Basin the transition to semi-anthracite commences somewhat earlier in this Southern coal-field, and in the Shamokin Basin, than it does in the Wiconisco coal-valley, where this variety is confined almost to the W. end of the trough. It is also shown that the semi-bituminous coals are found only in the Southern Basin, and that the transition from the semi-anthracites to these there takes place, considerably East of the Westernmost meridian of the semi-anthracites of the two other basins. Had the Zerbe's Run Coal Valley been prolonged but a very few miles farther W., the present rapid increase in that direction of the volatile matter in this coal shows that it too would have included the semi-bituminous class.

The causes not only of the general gradation in composition, but of the local differences in the progress of this curious transition in the bitumen above described, are plainly indicated in the particular geological structure of the respective coal-fields. Applying the theory of the cause of the de-bituminisation of our coals to the inequalities of composition, it is important to observe, that the phenomena are truly those of a baking and metamorphism of all the strata by an intense and pervading heat; that this heat has obviously been in greater excess in the E. than in the W. tracts of the anthracite country, and has been even differently operative, upon the different beds of coal, in proportion as these were encased in more or less conducting strata, or in strata more or less pervious to the escaping volatilising gases and bitumen. Independently of the satisfactory evidence presented by the transition of the coal itself, we have proofs, in the altered character of the other members of the formation—the shales and sandstones—and in the conditions of the rocks external to the coal-basins, that the igneous action was most intense towards the E. In that quarter the shales or mud-rocks of the Kittatinny Valley have been so thoroughly baked as to have been converted into roofing-slate; and not only this formation, but all the other strata from the Schuylkill and the Lehigh to the Delaware rivers, are traversed by a system of close-set, parallel, uniformly-dipping cleavage-planes, in token, not to be overlooked, that the drying and polarising agency of internal heat was here exerted in its fullest energy. Westward from the sources of the Schuylkill, both within and outside of the coal-fields, the parallel South-east-dipping cleavage pervades the argillaceous masses in a constantly-declining degree, so that the same rocks which near the Lehigh are almost indefinitely divisible into thin parallel slates, have had, in the country between the Schuylkill and the Susquehanna, this polarity less intensely imparted to them, and break, by two or three intersecting sets of planes, either into rhombs or elongated horizontal pencils. This declension in the metamorphism of the shales or mud-rocks is in parallelism with the similar change in the cleavage of the coal itself, which, in the anthracites and semi-anthracites, occurs only in one direction, and is parallel, and in the softer semi-bituminous variety in two or more intersecting directions, resulting in a columnar fracture.

But we have still more positive proof of the truth of the view here taken, that the E. portions of these anthracite fields were more invaded than the W. by volcanic heat, in the fact that it is only adjacent to the former that any igneous mineral dykes or veins of molten matter, injected during the elevation of the coal strata, burst through the crust to the surface. Along the chain of the South Mountains or Highlands, from the Delaware to the Schuylkill, occur numerous intrusive dykes of magnetic iron-ore, greenstone, and other igneous rocks; while in the humbler range of hills scattered between the Schuylkill and the Susquehanna, these injections are much more rare. In the E. quarter, therefore, the earth was far more violently rent than in the W., and we are conducted to the almost necessary inference, that the districts respectively opposite these differently disturbed and heated belts were themselves in a somewhat corresponding degree differently heated; for although not a single intrusive vein or dyke is to be met with in all the anthracite country, there evidently issued through the coal strata a copious efflux of hot volcanic gases and steam by the dissimilar heating and distilling power of which, in the different districts, the coal itself was variously de-bituminised and metamorphosed.

CONDITIONS IN THE COMPOSITION AND STRUCTURE OF COAL AFFECTING ITS ECONOMIC VALUE.

It will assist us to estimate more correctly the relative practical values of different coals, if we consider the various qualities which good coals should possess, and the extent to which certain conditions in their constitution influence their efficiency as fuels.

The chief useful applications of coal, at the present day, are—to the warming of houses, the generating of steam, the smelting of iron and some other substances, the burning of bricks and lime, and the manufacture of illuminating gas.

For all these and sundry other uses, excepting the making of gas, the semi-anthracites, it is conceived, will be found quite as well suited as the hard, dry anthracites, while they are undoubtedly even better adapted to some particular applications.

A good anthracite, for domestic purposes, should be as free as possible from *sulphur* and from *ashes*, and it should ignite readily, and maintain its own combustion until entirely consumed, and not under too intense a temperature. A most essential requisite to the health and comfort of all communities, living in cool and especially in variable climates, is the maintenance of a tolerably uniform in-door temperature; but it must be acknowledged that the harder anthracites, burned in the crude and unscientific modes almost universally in practice, absolutely resist control in this respect. When fully kindled, in quantity enough to make a lasting fire, either in an open grate or a stove, almost any compact anthracite will heat the space around it to excess, and moreover, cause a dryness in the air, which is extremely unwholesome. These coals can only burn at a very elevated temperature, and with an abundant admission of atmospheric air, and they therefore oppose much difficulty to all attempts, unless made with very exact adjustments, at restraining their combustion to the satisfactory point of a low mild heat.

The semi-anthracites are susceptible in this respect of much more easy management. Under a strong draught, which they require for full activity of combustion, these coals (as our Table of comparative results will show) burn quite as fast, and create as extreme a heat, as do the hardest anthracites; but with the ordinary supplies of air, they consume slowly, and give off only a moderate and comfortable temperature.

The chief reason of this difference is, in their readily breaking into small fragments on the fire, and damping thereby the draught by the increased friction which the air encounters. When the current of air, on the contrary, is strong, the effect of the greatly-extended surface resulting from this subdivision overrules the influence of the friction, and these coals then burn with a rapidity and an intensity of heat which give to them an efficiency for other purposes, decidedly superior to that of any but the very purest and quickest-burning among the true anthracites. The greater amenability to control of the softer coal, compared with that of hard refractory anthracites, renders it especially well suited for domestic consumption in stoves and cellar furnaces, as already amply demonstrated by numerous and protracted trials. In these arrangements it is altogether more easy with it than with common hard coal to maintain a steady and sufficient temperature in an apartment or throughout a house for many hours together, or even a whole day and night, without a renewal of the fuel. Its important property of burning at a relatively lower temperature keeps it enkindled to the last; and, as a consequence, it leaves behind it after combustion almost no unburned residuum. Not so with the densest dry anthracites. These rage for a while under a moderate strength of draught, and then, at a point much short of entire consumption, they die out from decline of temperature, leaving a serious amount of fuel wasted, and causing in household economy no trivial inconvenience. To obviate this form of waste and extra labour, the fires are replenished with fresh fuel when it is not required, and then an almost insupportable heat is created, while a still larger waste, with much increased discomfort, are the consequences.

Another material point of difference in the fitness of the two classes of anthracites for domestic use, when burned in open fires, is in their sensibly dissimilar influence on the dryness of the surrounding air. The atmospheric moisture exists as an independent gas, inter-diffused with the other less variable elements of the air. Any local source of aqueous evaporation, or of chemical production of water, as in the combustion of wood or of bituminous coal, suffices to spread a more or less diffused humidity throughout the rest of the space, by virtue merely of the power inherent in every vapour and gas to diffuse itself among the others, uninfluenced by mechanical currents. Thus an actively-blazing wood fire, by producing a copious supply of watery vapour in its smoke, serves slightly to moisten the atmosphere around, because, notwithstanding that the flow of air is towards the fireplace, the humid particles percolate through the current by a more active force in the opposite direction. But such is not the case where a fuel, like a hard dry anthracite, is burning in presence of the atmosphere of the room. Being almost destitute of hydrogen, it develops by its combustion little or no water, while at the same time it creates a great avidity for moisture in its own smoke, and in the air around it, by the high temperature to which it heats these. It therefore occasions a filtration or diffused movement of the watery particles of the atmosphere of the room towards the fireplace, and not from it. A mass of such fuel ignited is, in other words, an *absorbing vacuum* for moisture, while a blazing wood or bituminous fire is a *dispersing plenum*. In this opposite action of the two kinds of fuel, we find the explanation of the obvious and acknowledged difference, in the agreeableness and wholesomeness of their respective open fires.

Now it is deserving of remark, that this detrimental drying action of the anthracites is possessed in a decidedly smaller share by the soft, free-burning, and gaseous semi-anthracites, several of the characteristics of which depend on their containing a sensible proportion, often one half as much as belongs to bituminous coals, of the important moisture-producing element, hydrogen. All the non-bituminous coals desiccate the air too much; but these do this least, and will be found, upon this account, decidedly the most wholesome class, if open fires are used.

Another very important application of fuel is the development of steam, either for warming buildings or propelling machinery. In this latter function, as the foremost of all the agents employed by civilised man for his industrial ends, and as incomparably the most condensed form of mechanical power which he can hope to wield, coal is rapidly becoming the chief material minister to human progress. Whatever, therefore, relates to a correct theory and practice in applying it to steam, must be regarded as of paramount interest. Any careful experimental inquiry into the properties and relative value of the semi-anthracites—a variety hitherto but little investigated—is therefore, upon general considerations, no less than local ones, deserving of attention.

The principal requisites of a good fuel for steam purposes are easily enumerated.

1. It should possess a high absolute evaporative power.

2. It should at the same time, as far as is compatible with the foregoing property, kindle readily, and burn with great celerity, generating a large body of steam in a short time.

3. It should be easily managed, and steady in its combustion, and to this end its ashes or earthy matter should tend as little as possible, to choke the draught of the grate by fusing, even at an extreme heat, into an adhesive clinker.

4. The fuel should be free from any excess of incombustible matter, as this, all other things being the same, will materially impair its efficiency; and its ashes should produce but little clinker.

5. It should be exempt from any considerable amount of sulphur, for this tends to corrode the flues, and is otherwise detrimental.

6. Whatever volatile matters it possesses should not be bituminous, but should be in the condition of the free gases, susceptible of ignition or disengagement without smoke; and these volatile matters should not exist in any greater amount than will suffice to give rapidity of combustion to the fuel; any larger proportion is at the expense of its heating power.

7. A fuel should not be too cohesive and refractory on the fire, nor yet too tender and divisible. In the one case its combustion will be slow and irregular, and in the other it will be still slower for want of the requisite draught. A certain degree of spontaneous frangibility, such as is shared by some of the less-resisting anthracites, and by many of the firmer semi-anthracites, appears from practice and experiment to be the structure best suited to extreme vigour and steadiness of combustion.

8. For certain purposes of domestic consumption, coals should be capable of sustaining a mild and steady combustion, and of remaining ignited at a low temperature with a comparatively feeble draught.

9. For certain uses, it is important that a coal should unite with a high evaporative power such a degree of density and structure combined, as will enable it to contain a relatively large amount of carbon in a given space. This capa-

bility of being economically stowed or packed away, is a point of daily-increasing consideration. The difference between the least and the most stowable anthracites, is as much as 16 per cent, and between the closer-packing anthracites and the lighter and more open bituminous coals, it even exceeds 20 per cent.

10. It is likewise desirable that a coal should possess sufficient tenacity in the lump, to bear the abrasion incident to its transportation, without serious waste by reduction to fine coal.

These are the principal qualities in coals which materially influence their economical value. No one variety will ever be found to unite them all, for some of them can hardly coexist in a high degree in the same specimen. The relative worth to be assigned to these several desiderata, is itself variable with the uses to which the fuel is to be applied. But having a specific application in view, it is easy to ascertain what union of compatible qualities will insure to a coal the highest possible efficiency. This once determined on, the records of judiciously-conducted practical experiments will then prove the proper guide in selecting the kinds required.

If I now present a condensed synoptic view of the composition and comparative efficiency of a number of well-known and characteristic American and British coals, derived from the able experiments of De la Beche and Playfair, and the full and careful researches of Johnson, and from our own trials, the reader will have before him all the data necessary for determining the general relative excellence of the several species, and the rank which each particular coal can claim, when measured by either of the practical standards established.

In offering this tabular statement, it is expedient to remark, that in all such comparative estimates of the values of different fuels, strict impartiality and accuracy require that the conditions under which the different varieties are tested, should be modified, as far as possible, to meet their individual peculiarities. A just comparative view will embrace not merely a faithful account of the chemical and physical characters of the several coals, but the results of sundry trials of their efficiency in numerous modes of their application, as in warming, generating steam, and smelting, and with the circumstances variously adapted to bring out the fullest economy and power of each kind of fuel. Our own investigation of the semi-anthracites* embraced, together with a chemical analysis of several average specimens, a determination of their usual specific gravity and power of being economically stowed, and in addition, many comparative trials of the combustible efficiency of the coal in open fires and stoves, and under a set of four well-arranged steam-boilers. No actual experience has yet been had touching the suitableness of the semi-anthracites to the various processes of iron-making, but several important inferences may be deduced from what has been ascertained of their composition and structure, and their fitness for other uses, involving the same combination of qualities essential to a good smelting-coal.

In the experiments made upon the evaporating power of the coals, due care was observed to insure comparable results, so far as was practicable, upon good boilers, without any special adjustments for adaptation to differences in the fuels and working for a copious production of steam. As the furnaces and flues connected with these boilers were planned especially to meet the requirements of the harder kinds of anthracite—the grate bars being three-fourths of an inch apart—the conditions have been rather adverse than otherwise to the impartial claims of the semi-anthracites.

It will be seen that in planning and conducting these researches, we have not aimed at any extreme scientific precision, or even at procuring results by perfection in the apparatus or otherwise, beyond such as are easily obtainable in the way of good daily working practice. The two kinds of coal were deemed sufficiently alike, after all, to yield approximately comparable values, and it is very doubtful whether the most refined apparatus, unless variously adapted to the peculiarities of each fuel, where the coals are more diversely organised, as in comparative trials between the bituminous and anthracitic varieties, can ever exhibit more closely than ours has here done the respective merits of the different species.

While, therefore, we do not pretend to rank our experiments with the above-mentioned skilfully-conducted observations of De la Beche and Playfair and their assistants, or the elaborate researches of Professor Johnson, and while we are aware that the very active blast we used was incompatible with as economical a combustion as those experimenters produced; we are content, for the sake of affording an insight into the relative efficiency of the semi-anthracites, to tabulate our results with those of the esteemed authorities we have named.

The design of the General Table which here follows, is to present in one condensed comparative view the more practically important physical and chemical characters, manner, and rate of burning, and evaporative power and activity, of the chief American and foreign coals hitherto subjected to experiment; and to show, moreover, by a series of impartial averages, the relations to each other, in these respects, of the four great classes into which the coals naturally rank themselves.

Let us now review concisely, by aid of the following Table, the relative values of each leading class of coals. In this inquiry it will be proper to judge of the rank of each kind of coal by the extent to which it possesses the several qualities already mentioned as the chief requisites of every good fuel. But it must be carefully borne in mind, that, though the numerical results here exhibited offer a fair approximate measure of such relative rank, they are not to be adopted in certain cases without allowance for the modifying influence of differences in the modes of measuring and burning the coals.

---

* See *Reports on the Combustible Qualities of the Semi-Anthracites of the Shamokin Coal-fields.* By Augustus A. Hayes, M.D., and Prof. H. D. Rogers. Boston: 1851.

[TABLE.

TABLE

(SHOWING THE RELATIVE PROPERTIES AND ECONOMIC RANK OF THE DIFFERENT CLASSES OF COAL).

		DENSITY.			COMPOSITION.			CONDITIONS OF THE COMBUSTION.						EVAPORATION.			RANK.
	Names of Coals.	Specific gravity.	Weight of 1 cubic foot broken in lb.	Stowage of 1 ton in cubic feet.	Volume comb. matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.		Weight of Coals burned.	Clinker alone from 100 lb. Coal.	Total Waste in Clinker & Ashes.	Pounds burned on sq. ft. of grate per hour.	Hours required to get up full action.	Pounds of Water evaporated.	Pounds of Water evapd. from 212° to 1 lb. Coal.	Rate of evaporation, or lb. evpd. per hour to sq. ft. gt.	In the order of combined evaporative speed and power for equal bulks.
Hard Anthracites.	Rhode Island (Hayes),	1.79	...	...	3.00	77.00	16.00	...	10560.	10.00	10.90	9.44	...	63525.6	7.40	69.85	...
	Beaver meadow—mean of 3 kinds (Johnson),	1.55	55.06	40.03	2.52	90.20	6.13	...	4009.5	1.00	9.35	6.48	3.15	...	9.54	61.82	3403.80
	Lehigh (Johnson), . .	1.59	55.32	40.50	5.28	89.15	5.56	...	3838.2	1.08	7.22	6.95	3.27	...	8.93	61.16	3383.31
	Forest Improvement (J.)	1.47	53.66	41.75	3.07	90.70	4.41	...	3810.	0.81	6.97.	6.52	3.32	...	10.06	65.69	3519.55
	Lackawanna (Johnson),	1.42	48.89	45.82	3.91	87.74	6.35	...	4112.5	1.24	8.93	6.45	2.67	...	9.79	63.15	3087.40
	Mount Laffy (Hayes and Rogers), ...	1.54	53.50	41.87	...	...	...	...	8100. largest expt. 34118.	12.80	19.00	9.23 highest, 10.00	...	63525. largest expt. 261513.	9.32 highest, 10.19	85.88 highest 92.32 9.08 X 10.19	4594.6 highest, 4949.8
	Welsh Anthracite (De la Beche & Playfair),	1.37	58.25	37.23	5.50	91.44	1.52	...	...	...	9.58	8.65	...	...	9.46	81.83	...
	Averages of the 4 first Penn. Anthracites, with Johnson's apparatus, ...	1.50	53.23	42.02	3.69	89.45	5.61	.044	3964.5	1.03	8.12	6.60	3.10	...	9.58	62.93	3349.8
Semi-Anthracites.	Zerbe's Run—mean of 5 trials (Hay. & Rog.),	1.40	53.73	41.69	7.31	84.25	6.11	.000	8000. largest expt. 26408.	3.45	11.70	9.26 highest, 10.20	...	64960. largest expt. 237427	9.58 highest, 10.60	88.92 highest, 108.10	4777.4 highest, 5648 2
	Lykens Valley (John.),	1.39	48.56	46.13	6.88	83.84	9.25	.091	2471.	4.40	12.24	6.92	2.63	...	9.46	65.46	3973.66
Semi-Bituminous Coals.	Dauphin, Yellow Spring (Rogers), ...	...	...	...	11.00	76.00	12.10	...	...	...	...	...	...	...	...	...	...
	Dauphin, Rattling Run Gap (Johnson), . .	1.44	50.54	44.32	13.57	74.24	11.49	.269	...	3.50	16.36	68.6	0.83	...	9.34 highest, 9.66	64.07	3238.09
	Cumberland, Md.--mean of 6 samples (John.),	1.35	53.13	42.17	14.20	73.95	10.41	.714	...	3.12	10.70	7.10	1.45	...	9.98	70.85	3764.26
	Welsh Semi-Bituminous—average of 5 varieties * (De la B. & Pl.),	1.33	58.60	...	13.4	81.88	4.72	.610	...	...	...	...	...	...	8.94	84.5	...
	Averages of the above Penn. and Md. S. B. Coals (Johnson), .	1.39	51.83	43.24	12.92	74.73	11.33	.531	...	3.31	13.53	6.98	1.14	...	9.66	67.46	3496.4
Bituminous Coals.	Richmond Va. Cls., of the Oolitic Epoch—mean of 11 Collieries (Johnson), . . .	1.34	49.25	45.71	29.43	58.10	10.90	1.232	3606.4	4.89	11.78	7.41	1.33	...	8.07	59.80	2945.15
	Foreign Coals—mean of 6 kinds † (Johnson),	1.34	50.00	44.86	31.81	57.66	8.44	0.433	3247.7	4.20	8.71	8.89	0.93	...	8.05	71.56	3578.00
	West of Alleghany Mts.—mean of 2 kinds ‡ (Johnson)	1.26	47.23	47.43	30.28	56.68	6.02	0.160	2465. Cannelton.	1.28	6.68	11.09 Canneltn.	0.50 Canneltn.	...	7.77 Canneltn, 7.34	81.40 Cannelton.	3844.50
	Averages of the above Bituminous Coals, .	1.31	48.82	46.00	30.50	57.38	8.45	0.608	3106.3	3.45	9.05	9.13	0.92	...	7.96	70.92	3456.0
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

* The Coals are, Graigola, Ward's Fiery Vein, Binea, Pentrefelin, and Duffryn.

† Pictou, Sidney, Cunard's Pictou, Liverpool, Newcastle, Scotch. ‡ Pittsburg, Cannelton.

The *first* of the qualities to be compared is that of divisibility during combustion. This property, due chiefly to the degree in which the respective coals are intersected by joints, but due also in part to a condition of the cohesive force, and to a low power of conducting heat, as in unannealed glass, is possessed in the least share by the more compact of the anthracites, and reaches its maximum in the softer semi-anthracites. In the semi-bituminous coals of some districts, that of the Alleghany Mountain, for example, the mere mechanical subdivision by innumerable intersecting cracks is in its highest excess, and leads to much waste under severe handling and rough transportation; but upon the fire the minute cubical and columnar fragments cohere together as they coke, and the benefits of that degree of dissolution, seen in the free-burning semi-anthracites, are to a great degree lost.

It has been already stated that the semi-anthracites of the W. end of the Shamokin Basin show the advantages in a sensible degree of this fissured structure. While the actual heating power of the coal, when aided by a proper draught, is not at all impaired by it, the rate of the combustion and evaporation is materially hastened. The strong cohesion of the true anthracites, and the agglutination of the fragmentary semi-bituminous coals, cause these in different ways to retain more of the lump form upon the fire, but the semi-anthracite opens to the current of oxygen a prodigious increase of surface for combustion. When we reflect that a lump of fuel burns only at its surface, that the activity of the combustion is in proportion—other things the same—to the amount of oxygen which can reach an equivalent amount of fuel surface in a given time, and that this amount augments progressively by the subdivision of the fuel, until it is checked again at a certain point by the retardation of the draught from the increased friction—we shall comprehend at once why a particular degree of divisibility may be the most favourable of all for producing high rapidity of combustion. The burning of carbon in atmospheric air, is in part analogous to the dissolving of any other solid in any other fluid. Chemically regarded, it is a case of solution, with formation of new compounds. But such solution is notoriously promoted and hastened by subdivision of the solid body, as we witness in the everyday practice of reducing sugar, salt, and especially the substances which most resist dissolving, to small fragments, or even to fine powder.

The *second* element of practical value in the coals, the first introduced into the Table, is their capacity for *economical stowage*, deduced, not from the specific gravity of solid pieces, but from the ascertained weight of a cubic foot measure of the coal in broken fragments of a standard size. The degree of compactness into which a coal in the state of lumps will stow itself, by no means depends altogether on its specific gravity. It is largely influenced by the shapes into which the coal naturally breaks; those varieties, as it has been well remarked, packing with least waste or intersticial space, which split by parallel joints, and form cubes and other rectangular figures with flat surfaces. And again, the total quantity of efficient fuel which can be stowed in the lump form in a given bulk, will be in proportion, not simply to its weight in fragments per cubic foot, but to this element, and that of its purity from earthy or incombustible matters combined. The present condition and future prospects of ocean steam-navigation, where the fuel-room necessarily encroaches so largely on the freight-room of the steamers, make this quality of stowing closely, an element of great importance. Indeed, the time seems fast approaching, when no other coals will be chosen for the great and growing purpose of replacing the use of the wind upon the seas, but such as unite in the highest compatible degree the three primary qualities of *dense stowage of efficient combustible matter, high evaporative power, and great activity of combustion.*

It will be seen, upon consulting the Table, that though the average specific gravity of the hard anthracites of Pennsylvania exceeds that of the semi-anthracites in the ratio of 1.50 to 1.40, their weight per cubic foot, in the broken state, is very nearly the same, their capacity for stowage being in the near proportion of 41.69 to 42.

Compared with the semi-bituminous coals, the semi-anthracites show an almost exactly equal power of packing, bearing in this respect to the average of the Dauphin and the Cumberland semi-bituminous coals the ratio of 43.07 to 43.24 cubic feet per ton. Here, however, it requires to be noticed, that difference of specific gravity enters as a fallacious element, increasing from the fact of the superior weight of slate over true coal, the apparent quantity of real fuel in the cubic foot of the semi-bituminous coal beyond its actual amount. These semi-bituminous coals exhibit an average of 11.33 per cent of earthy matter, to 6.11 per cent in the semi-anthracite, showing a decided disparity in the proportion of effective combustible matter which the ton weight of each will stow. Where the two classes are of equal purity, the semi-anthracites will, in the larger majority of specimens, be found to be the heaviest, and to occupy, therefore, either solid or when broken, the least bulk.

Comparing again the nearly equal powers of stowage of the three already-mentioned classes of coals with that of the bituminous coals, both domestic and foreign, we find a materially greater difference; these latter requiring on an average as many as 46 cubic feet to hold 1 ton of the fuel. Between the densest Beaver Meadow anthracites, measuring 40 cubic feet to the ton, and the least compact Cannelton bituminous coal, taking rather more than 47.5 cubic feet, the excess of bulk is nearly 19 per cent above the first.

It will be seen from the Table that the Lackawanna coal, which, when pure, approximates sensibly towards the semi-anthracite in its physical structure, is not only light in the solid mass, but relatively bulky when broken.

The figures in the Table indicating the weight per cubic foot of the Welsh coals, both anthracite and semi-bituminous, so far exceed those for the American coals of the same classes, and differ, moreover, so widely in their ratios to the corresponding specific gravities of the coals themselves, when compared to the ratios of the cubic-foot weights of the American coals to their specific gravities, that we are compelled to infer that the mode of estimating the cubic foot of lump coal by the British experimenters was essentially different from that adopted in this country by Professor Johnson and ourselves. In no other way can we account for the large disparity exhibited. This is so serious, considering the lightness, by specific gravity, of the Welsh specimens, that it will be safest not to attempt any comparison here between either the stowage of the corresponding coals of the two countries, or between the rank they respectively hold in the order of their evaporative power for equal bulks, which includes the former as one of its elements.

The *third* important relationship of the coals to each other, exhibited by the numbers in the Table, is that of their *composition*, as determined by proximate analysis, defining the proportions respectively of the volatile combustible matter, the fixed carbon, and the earthy or incombustible residue. In this aspect, it will be seen that the four several classes of coals display a regular augmentation in the average per-centage of the volatile combustible matter, this being about 3 1-2, 7 1-3, 13, and 30, in anthracites, semi-anthracites, semi-bituminous, and bituminous varieties respectively. The corresponding declension in the amount of the fixed carbon is represented by the numbers 89 1-2, 84 1-4, 74 3-4, and 57 1-3; while the incombustible or earthy matter is in no established proportion or gradation, but varies with the individual coal-seams, and even, in fact, with their different subdivisions. Nevertheless it will be noticed as a general feature, that the anthracites and semi-anthracites of the Table are decidedly purer than the two bituminous classes.

An analysis of a coal into its *ultimate* elements shows that its combustible matter, consisting of carbon, hydrogen, oxygen, and nitrogen, embraces, except in the dryest anthracites, invariably a larger amount of carbon than is ever left in the form of coke when the volatilisable portions are distilled or burned away. The cause of this is, that a part of the gases are in chemical combination with a portion of the carbon, while another part, especially the hydrogen and oxygen, though probably in a free state in the pores of the coal, are ready at a low heat to seize upon another equivalent amount of the carbon, so that from both the sources a greater or less proportion of the total carbon, depending on that of the gases, is burned in the gaseous form in the flame and smoke of the fire.

A *proximate analysis* of a coal by heat merely, separates first the free or uncombined water, varying from less than 1 to 3 or more per cent; next, the whole of the combustible volatile matters, including the portion alluded to of the total carbon; then the fixed carbon of the coke, and, as the final residue, the earthy ashes.

As the useful values of coals are variously influenced by the presence and nature of their volatile combustible part, it is expedient that I here notice the chief results of observation and experiments in relation to this ingredient.

One effect of a large excess of volatile matter in a coal, is to impair seriously its heating power. All the researches recorded in the Table concur to prove this point. Comparing the average volatile combustible matter with the average weight of water evaporated from the temperature of 212 degrees by 1 lb. of coal of each of the four classes, the full bituminous kinds display an evaporating power of less than 8 lb. to more than 9.5 lb. for the other three varieties. Numerous elaborate researches go to show, that with very many samples of bituminous coals the heating effect of the whole volatile portion of the fuel is almost "absolutely negative;" and it has even come to be a prevailing opinion, that the total evaporative efficacy of a bituminous coal is no greater than that of the coke or fixed carbon which it contains. Certain it is, that in the ordinary way of practice with the boiler-furnaces in use, the absolute equivalent of heat belonging to the coke (all of which is not procurable, however) exceeds considerably, with rare exceptions, that which is actually produced by experiment on the original coal. Some authorities, among them Professor W. R. Johnson, have evolved results which seem to indicate that the heating efficacy of a coal is measured by that of the whole of its carbon, rather than by that of its coke, which is but a portion, and general experience would appear to sustain this relationship. We must keep carefully in view, however, that such a proportion is liable to be constantly departed from, through imperfections in the furnaces constructed for bituminous coals, and that, moreover, the deviation from this or any other fixed ratio, will vary with the variable nature of the bituminous compounds which different coals contain.

The special qualities of the different bituminous and semi-bituminous coals are not caused solely by the proportions of the volatile matter they contain, but are as intimately connected with their chemical constitution. A most important practical distinction in coals, is that between the caking and the open-burning varieties; and upon these characters, even more than upon their mere amount of bituminous matter, depend their adaptations to many economical uses. For the manufacture of coke, and the production of a hollow forge-fire—where this is needed—the melting coals are valuable; but where a very active combustion is demanded, the open-burning kinds are preferable, since, by not fusing, but only partially swelling, they afford a freer passage to the oxygen, and give out a higher heat. A comparison of the analyses of coals, with the observations upon their manner of burning, shows clearly that, except within certain limits, the proportion simply of bituminous matter has little to do with their free-burning or their caking qualities. As a general rule, the small amount of combustible volatile matter in the semi-bituminous coals, is associated with the absence of any marked tendency to cake into a close or hollow fire; but among the true bituminous class this tendency appears to bear no relation to the degree of bituminisation, some of the driest of these having not more than 25 per cent of volatile matter in all, being decidedly fusible and close-burning; while there are others with not less than 45 per cent, which burn with a free open fire.

It would appear "that the property of caking generally increases with the quantity of hydrogen and oxygen in the coal, and especially with that of the hydrogen," yet to this rule there are found some striking exceptions; and we are compelled, in considering all the phenomena, to refer the different tendencies in various coals to soften and cake, to the existence of different kinds of bitumen, or at least to differences in the constitution of the coals as respects the mode in which the gases are combined with the carbon. This is a subject of much practical and scientific interest, and one which calls for further investigation at the hands of chemists.

A review of all that has been done in relation to this question of the effect of the volatile matter, seems to justify this general statement, that the evaporative power of a coal never exceeds in practice that due to its whole amount of carbon, and is oftentimes as low as that procurable from its coke alone; while the extent to which it falls short by imperfect combustion, of that fullest attainable measure of efficiency, is greater in proportion as the coal is more bituminous. The cause of the waste of so much power in the combustion of bituminous coals, notwithstanding the intense temperature developed by the gaseous products while burning, is clearly to be ascribed to the amount of heat absorbed in raising the cold fuel to the point of ignition, and the yet larger portion made latent by the change of the volatile portions from the solid to the gaseous condition, while only a part of the heat of their combustion is returned. Unless burned with a very intense heat, and with a large excess of atmospheric air, a part of the carbon of the coal passes to the chimney in the form of carbonic oxide gas, having but half undergone combustion, or having given out but half of its possible full product of heat. At the higher temperature evolved by the drier coals, a more total combustion takes place with the immediate production of carbonic acid, and the entire amount of heat produced by oxygen and carbon is developed.

It must not be inferred from what has now been said, that every amount of volatile matter in a coal, whether much or little, must necessarily impair its heating power. The whole tenor of the researches made would seem to contradict this, and to show that the possession of a certain proportion, within restricted limits, exalts not merely the activity or speed of the combustion, but the total heating power, as measured by the evaporative effect. Thus it appears that both the semi-anthracites and the drier semi-bituminous coals, when they are properly burned, rather surpass, in calorific energy, the class of the hard anthracites. A small share of the easily-combustible volatile gaseous matter seems very useful, by promptly kindling the solid carbon with which it is in contact, and thus enabling the fuel to dispense with so vast a current of cooling air, as it is demanded for the full ignition of a dry refractory anthracite. But to confer on a coal the highest heating efficacy, experience and practice would suggest that the proportion of gaseous matter in it should be no more than just enough to facilitate the kindling of the freshly-supplied portions, by quickly transmitting its own combustion to the other parts, but not so large as to occasion any sensible waste of power. It is therefore, as adding to their activity without impairing their strength, that we regard as so important the presence of the trivial quantity of free-burning gases in the semi-anthracites.

Another class of ingredients in coal, the proportions and qualities of which are equally influential with those of the gaseous products, are the earthy matters. These, like the volatile constituents, are somewhat variable in their nature, and by the forms they take under different intensities of combustion, much affect the efficiency of the coals to which they belong. Being differently fusible themselves, and affecting differently the fusion of each other, no two of the earths, alkalies, or metallic oxides, of the ashes, but differ in their agency when subjected to an elevated heat, and their mutual reactions are moreover changed, as the temperatures are changed to which they are exposed. It hence arises that the residue from many coals melts to a large extent, under no very intense combustion, into various descriptions of hard semi-vitreous slags; others yield a less stony clinker; and some again, at a far more elevated heat, result only in a partially agglutinated spongy open cinder, or even in a pulverulent or flaky ash. There are perhaps no coals, whose ashes, when exposed to the extremest heats procurable by artificial blasts, will not soften to a cohering cinder, or even melt in part into a stony clinker; but as the tendencies to these several degrees of fusion are very various, it proves to be a distinction affecting the practical value of coals, which is of the utmost importance. In domestic consumption, where the heat of combustion is comparatively moderate, the quantity rather than the quality or fusibility of the ashes is the point of greatest consideration; but where an excessive and melting heat is required, as in many modes of generating steam, the practicability of employing a coal at all will oftentimes be determined by this one quality of the clinkering of the ashes. In all such circumstances, those coals are best, the ashes of which are of a nearly pure white, and which, with large amounts of silica and alumina in their composition, contain little or no alkali, nor any lime, nor oxide of iron. Of this character are the earthy residua of the best white-ash anthracites of Pennsylvania, and, in an eminent degree, the ashes of some of the semi-anthracites.

The columns G and J in the Table, the one relating to the per-centage of clinker alone, the other to the per-centage of the total waste, including clinker ashes and fine particles of intermingled unburned coal, are instructive in this connection in several points of view, in disclosing, first, the different proportions of residue from different coals; secondly, the varying ratios for the different classes of coals, of the clinker formed, to the total waste, and of both of these to the actual amount of earthy matter; and again, the marked influence of an increased intensity of combustion by strong mechanical blast, in increasing where the coals are of the same class, and of equal purity, both the quantity of clinker and of total waste.

It will be noticed that the hard white-ash anthracites of Pennsylvania, all the samples of which, experimented on by Professor Johnson, appear to have been of at least full average purity, exhibit not more than 50 per cent of additional waste beyond the total quantity of earthy matter detected in them by chemical analysis, and not more than one-eighth of the total waste, in the form of clinker; while the Mount Laffy coal, investigated by ourselves, displays a waste very nearly double the actual amount of earthy matter, and a proportion of clinker to the entire waste of fully two-thirds. The reason for this important difference is obviously to be found in the dissimilar conditions of the combustion. The apparatus employed by Professor Johnson had only that activity of draught which could be supplied by a chimney 45 feet high, while the furnaces beneath our boilers, besides connecting with a tall chimney-stack, were artificially supplied with air by a powerful fan, 30 inches in diameter, driven at a speed of 480 revolutions per minute. In the one case, the heat was barely enough to fuse a small part of the ashes; in the other, it was so energetic as to melt two-thirds of the total quantity, and to augment the weight of the clinker formed, by enclosing unburned fragments of coal to the amount of several per cent.

The effect of the same extreme degree of heat was witnessed on the ashes of the semi-anthracite from Zerbe's Run, but to a less extent, from its greater infusibility. The total waste from this coal was on an average almost twice the absolute amount of earthy matter, but the clinker was between a third and a fourth part only of this total waste. In the case of the Rhode Island coal, a higher fusibility in the ashes, due to the presence of lime and other fluxing ingredients, resulted in the conversion of almost the whole of the waste matter into clinker.

Directing our attention for a moment to the clinker and waste from the semi-bituminous and bituminous coals, we perceive that while the ratio of the total waste to the earthy matter in the coal is very nearly what it appears in the anthracites, the proportion of clinker or fused matter to the whole residuum is, notwithstanding the far milder heat employed, nearly or fully as great as that from the semi-anthracite of Zerbe's Run burned under the strongest blast.

The explanation of this greater tendency in all these bituminous coals, compared with the anthracitic, to form clinker when exposed to the same heat, is to be detected in the different constitution of their ashes—the Pennsylvania anthracitic basins containing remarkably little lime, or other fluxing earths or alkalies, either in the substance of their coals, or in the strata which imbed them; whereas it so occurs that an influential quantity of one or more of those fusion-promoting ingredients appears in the ashes of almost all the fuels of the bituminous groups, as well those of the Dauphin and the Cumberland basins as those of the Richmond, the Trans-Alleghany, and the British coal-fields. In the ashes of the anthracites, the proportion of lime rarely surpasses 2 per cent, while in those of many of the bituminous coals it exceeds 5 or 6 per cent.

A *fourth* property of fuels, upon which their value for certain leading and rapidly-extending applications in a large degree depends, is that of kindling rapidly, and burning with great celerity when required. This quality in coal now enters as a large element in the conditions which control, through the agency of steam, the speed of commerce and the facilities of human intercourse, and which are enriching all the resources of civilised life by daily-increasing conquests over time and space. To it, therefore, even more earnestly than to the mere absolute heating energy of different fuels, must the researches of practical science henceforth be directed. An enormous amount of yet unawakened speed, as well as strength, still slumbers in certain forms of coal—the most condensed and the most tractable material shape in which a gigantic mechanical power is stored away. Only a portion of either of these has hitherto been evoked by art, and it is of the utmost importance that every point connected with our fuels, or with the conditions under which they are burned, which promises to procure from them either increased activity or additional total heat, should be closely investigated.

The peculiarities of mechanical structure and of chemical constitution, which are mainly influential in conferring on coals a high degree of combustible or evaporative activity, have been already stated, and it will suffice here merely to recount them. They are chiefly the absence of too extreme a density or cohesion; a certain medium amount of divisibility on the fire; a moderate proportion of combustible volatile matter, to quicken ignition and propagate the heat; the quality of keeping an open fire, and purity from much earthy matter, especially clinkering ashes.

The experimental results embodied in the Table, under the appropriate columns, express the relations of the various coals to each other in these respects. These, and the numbers in the columns K and O, giving the pounds of coal severally consumed per hour to each square foot of furnace grate, and the pounds of water evaporated per hour to the same amount of surface, embrace in one view both of the elements which modify the rate of activity of the different fuels, and the rates themselves, as ascertained by experiment.

Keeping in view what has been already carefully stated of the superior energy of the draught used in the experiments made by ourselves upon the Mount Laffy and Zerbe's Run coals, over that employed upon all the other results, and making our comparisons only between those results which were procured under similar or comparable conditions, we are guided by the Table to some instructive conclusions.

Looking first at the combustible activity of the several classes of coals, as determined by the apparatus used by Professor Johnson, we discern the fact, that the rapidity with which they burn is greater as they are more bituminous, or contain more combustible volatile matter. Thus, the anthracites burn at the rate of 6.60 pounds per hour on each square foot of the grate, the semi-bituminous coals at the rate of nearly 7 pounds, and the full bituminous coals at the rate of more than 9 pounds. The Lykens Valley semi-anthracite shows a rate of 6.92 pounds; the semi-bituminous coals of the Dauphin basin a rate of 6.86 pounds, and those of the Cumberland, 7.10 pounds; while the middle secondary bituminous coals of the James River basin, in Virginia, display the greater rate of 7.41 pounds to the same surface.

Turning to the figures indicating the respective *times* required for getting the boiler into full action, we perceive that the differences in the rapidity of kindling are much more marked than those of the rates of sustained combustion; the periods being for the four classes of coals, 3.10, 2.63, 1.14, and 0.92 hours respectively.

Giving our attention, in the next place, to our own experiments upon the hard anthracite and the Zerbe's Run semi-anthracite, with an artificial blast, we notice two points for comparison; first, a strikingly greater activity in the combustion of the same kind of coal under a strong current than under the gentle draught used by Johnson, in the ratio, for the anthracites, of 9.23 to 6.60; and, secondly, a trivial superiority in this particular on the part of the semi-anthracites of Zerbe's Run over the hard dry anthracite burned under like conditions. Under both rates of combustion the semi-anthracites display a rather higher activity than the true anthracites—with the ordinary chimney draught, a ratio of 6.92 to 6.60; and with the blower, one of 9.26 to 9.23; or by the longest and most complete trial with strongest blast, a ratio of 10.20 pounds burned to precisely 10 pounds.

It here is especially worthy of remark, that a moderate force of draught through the fuel seems to be the condition which is best suited to the fullest economical performance, speed and power both considered, of the semi-bituminous and bituminous coals, while to the anthracites a strong current is best adapted for the same ends.

The maximum heating effect from any coal is procured when the air passes it fast enough to burn entirely all the combustible matter it can surrender to it by its own heat; but when the current exceeds this rate, its influence is *counteractive,* cooling and quenching a portion of the burning matter, and driving it wastefully forward with the combustion not completed. The different ignitibility of the various classes of fuel sets of course different limits to this point of economical rapidity of blast and of combustion—limits which are sooner passed with the bituminous than with the anthracite coals.

Bearing upon this topic, it should be noticed that, since we inevitably lose a portion of the whole heat procurable from a coal, when, in our desire for speed or copiousness of combustion in a given time, we urge the fire too eagerly, we may perceive under what disadvantages the hard Mount Laffy anthracite and Zerbe's Run semi-anthracite were burned in our experiments, so far as mere evaporative economy is considered. Nothing speaks so strongly to the merits of both these coals as pure and efficient fuels than the fact under consideration, that the very high evaporative power indicated in column N of the Table co-existed with a rate of combustion so manifestly wasteful of heat as that shown in the preceding column K.

Another, and, as already intimated, a very essential quality in coals, affecting more perhaps than any other element their commercial value, is a *high absolute heating power.* This *fifth* principal relationship of the coals under comparison will be seen numerically expressed in the General Table, in column N, which shows the experimental effects of their combustion in pounds of water, evaporated from the standard temperature of 212° by 1 pound of each kind of coal. After what has been already pointed out on a previous page respecting the unfavourable rapid rate of the combustion in our own experiments with the hard Mount Laffy anthracite and the coal of Zerbe's Run, little farther need here be said in calling attention to the true relative evaporative power of the different classes and varieties of coals, than to suggest to the reader to make due allowance for that circumstance. Between the anthracites and the semi-bituminous coals burned under the same conditions of draught, there is a trivial difference of effect in favour of the latter, attributable mainly to the superiority of one or two of the Cumberland samples; but comparing either class with the true bituminous coals, we perceive that those which take the lead in rate of burning are far behind both the others in point of real efficiency. The pounds of water respectively evaporated were 9.58, 9.66, and 7.96, for the anthracites, semi-bituminous, and full bituminous coals.

In the next place, regarding the results of our own experiments, we observe that the average performance of the excellent hard anthracite we tried was sensibly lower than the average work of the similar anthracites burned by Professor Johnson with a gentler current; corroborating what we have alleged of the loss of evaporative economy from an over-active supply of air; but we perceive that notwithstanding the same important drawback on the full efficiency of the Zerbe's Run coal, the experiments demonstrated a decidedly superior evaporative power in the Zerbe's coal over the other in the ratio of 9.58 pounds to 9.32 pounds of water to the one pound of coal. When the conditions were less unfavourable for economical results, the product in steam was respectively 10.60 and 10.19 to each pound of fuel. During this best experiment the rate of combustion on the grate was, with the Zerbe's Run coal, as high as 10.20 pounds to the square foot per hour, while with the hard Mount Laffy anthracite it was 9.08 pounds.

This brings us to a review of the results shown in the next column (O) of the Table. This series of numbers, denoting the relations of the coals in their two important qualities of rate of burning and evaporating effect from equal weights—or, in other words, their *activity* and their *strength*—expresses more justly than any other portion of the Table the relative practical values of the several coals. It will here be seen that the anthracites, semi-bituminous, and bituminous coals, burned in the same apparatus, and under conditions best adapted to the two latter classes, display evaporative rates in the ratios of 62.93, 67.46, and 70.92 pounds of steam per hour to each square foot of grate.

Reducing our own results to the same units of time and surface, we notice that the hard anthracite produced as much as 85.96 pounds, while the semi-anthracite of Zerbe's Run went even beyond it in the proportion of 88.71 pounds, both of which are certainly very enormous products. But these, which are only averages, were much exceeded in the best states of working, when, after the middle of the week, the flues being all fully heated, the very copious blast employed was attended by a rather less than usual waste of fuel. At those times the highest activity and heating power united, yielded in steam the enormous product of 91.52 pounds from the hard anthracite, and 108.10 pounds from the semi-anthracite of Zerbe's Run.

In approaching the conclusion of this portion of our subject—the relative efficiency of the various coals in generating steam—we arrive finally at a comparison of the fuels in their three several aspects of evaporative activity, absolute heating power, and capacity of stowage combined: in other words, we have now to ascertain in what order the several varieties and classes range themselves, when each is estimated according to the degree in which it unites the three primary qualities of speed, strength, and compactness. The column P, the last in the Table, derived from multiplying together the three ratios expressing the pounds of coal burned on each square foot of grate per hour, the pounds of steam produced to each pound of coal burned, and the pounds of coal containable in each cubic foot of space, exhibits for the several coals their relative total values compounded of all these elements.

The Table here speaks for it itself. The numerical aggregates denoting the rank of the anthracites, the semi-bituminous coals, and the full bituminous coals, are respectively expressed by 3349.8, 3496.4, and 3462.3 pounds of water evaporated each hour on each square foot of furnace grate by each cubic foot of broken coal. It thus appears that the semi-bituminous coals surpass somewhat the bituminous, and that these exceed the true anthracites.

The relative rank of the hard anthracite of Mount Laffy, compared with the semi-anthracite of Zerbe's Run, is indicated by the ratio of the numbers 4598.8 to 4635.1, which denote the relative efficiency of each for marine navigation.

It will not be correct, of course, to compare these high results last recorded critically with the first series, since, as we have several times stated, the data included in them were procured from experiments differently arranged as to the rates of combustion. Yet, if we will keep in view the fact, that the strong current with which we blew our fires was probably as inimical to a large evaporative result per pound of coal, as it was friendly to an increased speed of combustion, the conclusion becomes very manifest that the numbers in the Table cannot be far astray in denoting the relative values of the coals reviewed in their triple aspect of combined *activity*, *strength*, and *portability*.

Having in the foregoing pages disposed of the various topics connected with the value of the several kinds of coal in their application to the production of steam, and with the merits of the semi-anthracites for that important purpose, it remains for me to add a few concluding remarks on the suitableness of this particular variety to the smelting and working of iron.

It is well known that purity in the fuel is a most important element of economy in the process of iron-smelting. A difference of only 5 or 7 per cent in the quantity of earthy matter in two coals is the source of a serious difference in the final cost which they involve. Not only must an extra amount of coal be introduced into the furnace to supply the deficiency caused by the additional impurities, but a still further portion is needed to melt the excess of ashes in the whole body of the fuel. The increased quantity of earthy matter difficult of fusion thus supplied, calls for a proportionate increase in the limestone or flux, which itself again exacts a certain amount of fuel to melt it with the additional ashes. Thus, from the one cause we require to make a triple augmentation to the fuel. If the ore employed be of a fair degree of purity, the surplus foreign matter, ashes and flux together, thus made to burden the furnace, will materially exceed 5 or 7 per cent of the total amount of earthy matter originally there ; and we therefore perceive that a seemingly trivial difference in the coals may cause a really important difference in the results. But besides these sources of extra cost, there are others which flow in their train. Among these are the items of expense for labour entailed by handling the additional fuel and flux, and the increased cinder from the furnace, and the more indirect loss from the lessened product which the furnace yields in a given time.

But the quality or nature of the extraneous matter has even a greater influence than the quantity upon the fitness of a fuel for the purposes of smelting. Of all the substances of a hurtful kind commonly to be found in coals, *sulphur*, usually combined with iron, forming minutely-disseminated sulphuret of iron, is by far the most injurious. The proportions in which it prevails in different coals are very various, many beds revealing scarcely a trace, while others again contain as much as 3 or 4, or even 6 per cent of this deleterious constituent. As a general fact, the anthracites and semi-anthracites are decidedly more free from sulphur than are either the semi-bituminous or the fully bituminous coals.

The better kinds of the two first-named classes exhibit, according to our analyses, but insignificant traces of it—not more in the *average* than 0.05 per cent, or one part in 2000 of the coal. The semi-bituminous coals, on the contrary, display an average proportion of more than ten times as much, or 0.53 per cent, while the mean amount for the three groups of bituminous coal is materially greater still, being as much as 0.61 per cent, or one part in every 164 parts of the coal.

Upon the view which I have advocated, that the anthracite coals are true *solidified cokes*, or the de-bituminised forms of the ordinary gaseous coals, the reason of their comparative exemption from sulphur becomes obvious and natural. The same highly-heated volcanic steam, in issuing through the strata, baking and metamorphosing the soft clays into indurated slates, and distilling out from the bituminous coal-beds their volatile bitumens and gases, would, by a well-known and often-practised chemical reaction, carry off the sulphur. By a process more refined and admirable than any which man can hope to imitate, these matchless varieties of coal have been ages ago de-sulphuretted, coked, and compactly pressed. They are the fuel of the world in its most elaborated, purified, and perfected form ; fine enough for any of the most delicate behests of chemistry, yet strong enough to achieve, with the aid of mechanism, the wildest and most daring dreams of speed and of physical power which the genius of invention can conceive.

METHODS OF SEARCHING FOR, OPENING, AND MINING COAL, PURSUED IN PENNSYLVANIA.

SEARCHING FOR COAL.

When the soil of a district is already known to be underlaid by the coal-formation, the first process adopted for the discovery of the seams of coal is searching the beds of the brooks and the hill-side ravines for fragments and particles of the coal itself, and of the black carbonaceous slate which is one of the commonest associates of productive coal-seams. This examination, which requires close attention and a quick and critical eye, is best pursued when the streams are shrunken in summer, or when the ravines are entirely dry, as the debris from the outcrops of all the strata swept into the channels by the freshets of the winter and spring, may be then readily turned over by the pick, and handled. A sagacious use of geological knowledge becomes of great assistance in this species of search. Guided by it, the explorer will select those ravines and other places, where, from his previous examination of the outcrops of the strata and the directions of the wash, he infers that the fragmentary matter of a certain relative lightness must have accumulated. Having once detected the debris of a coal-seam, it is usually a simple matter to trace it to the parent bed; for unless this rises very high in the adjacent hills, a studious tracing of the loose fragments up the channels or ravines will presently, by the sudden cessation of any signs of coal, show him that he has passed their source. He will then make assiduous use of a light pick, turning the soil and inspecting it very closely for indications of the "smut" of the seam—that is to say, for any stain imparted to the earth by very finely divided coaly matter.

Another mode of searching for coal is to commence at the stage just indicated: it dispenses, that is to say, with any preliminary inspection of the wash accumulated in the water-courses, and aims at detecting the smut of the coal-seam immediately by systematic digging in the supposed vicinity of the coal-bed. This method implies a knowledge of the topographical indications of coal, and nice judgment in availing one's-self of the conditions of the ground to test the presence of the looked-for bed with the least expenditure of time and labour.

The topographical features which indicate the presence of beds of coal in a group of Coal-measures are obvious enough to an eye once familiarised to them. They are merely indentations or benches in the sides of the hills, more or less conspicuous in obedience to certain geological conditions easily understood.

As every mass of Coal-measures embraces necessarily an alternation of stratified deposits, more or less unequal in their power of resisting the wearing or grooving action of water, and as water under great pressure has passed over the outcrops of all our coal-fields, the several strata betray in a remarkable manner their relative degrees of softness by the extent of the depression left upon their outcrops. The harder beds stand forth in steeper slopes, and under a less depth of wash or of debris; the softer occupy the indentations in the surface, and are generally the most deeply covered with soil. Seen in profile, the edges of a series of alternating hard and soft deposits will be distinctly undulated, and the undulation will be conspicuous in proportion to the inequality in the degree of softness, combined with two or three other conditions, such as the more or less prominent manner in which their outcrops have been exposed to erosive action, and the width or narrowness of the more easily trenched softer beds. For a full exemplification of this subject, the reader is referred to a former chapter on the effects of erosion on horizontal and variously-inclined strata. Now of all groups of sedimentary rocks, the coal-formation, especially where it has been partially metamorphosed, is that which exhibits the greatest known inequality in the hardness of its constituent beds, possessing, on the one hand, closely cemented, thoroughly compacted, massive strata of silicious sandstones, and even conglomerates; and, on the other, layers of soft shale almost as impressible as mud, and beds of tender coal, which, like the shale, are incohering and brittle from the presence of countless cleavage-joints and closely-set fissures. A mass of Coal-measures will therefore almost invariably betray the positions of its contained beds of coal—its thicker ones at least—by the indentations of the surface. It is the business of the coal-seeker then to study and interpret these. If the strata dip at a moderate angle, and the difference of resisting power in the strata is great, each thicker seam of coal will form, with its accompanying soft shales or slates, a wide, nearly level terrace on the hill-side. Lengthwise, this terrace or bench will undulate in height and advance and retreat on the flank of the hill or ridge to which it belongs, in conformity with the modelling of the ground, in a manner which has been explained in the chapter on Erosion, descending into the ravines with a forward or backward sweep obedient to the direction of the dip, and ascending high on the hill-side where the denudation has been least. These hill-side benches are discernible in almost every portion of the anthracite coal-basins of the State, being particularly conspicuous where they mark the outcrops of the very thick coal-beds of the lower or white-ash series, on the slopes of the main ridges bounding those valleys. They are beautifully distinct and regular on the flank of the Broad Mountain in the Mine Hill Valley, and are hardly less conspicuous on the N. side of the Pottsville Basin fronting the valley of Panther Creek, and near the Little Schuylkill. They are unusually distinct also throughout the Shamokin Basin, owing to the thickness of the lower coal-beds and the conglomeritic and firm character of the coarse sandstones which separate these, and which outcrop in alternation with them on the inner slope of the encircling mountains. Though a dense forest may conceal these terraces of the coal-beds, they are not wholly obscured by a clothing of tall bushes or a copse of young timber. When faint, they are best detected under a slant sun shining in a direction nearly coincident with the slope containing them. The accompanying Plate presents a view of a series of conspicuous benches on the N. side of the Panther Creek Valley, nearly opposite the Summit Mines of the Lehigh Company.

Surface-Shafting.—Having discovered by external signs the probable presence of a seam of coal which it is desirable to open or prove, the next process is to reach it by digging, and establish its thickness and the direction of its dip with the least amount of excavation practicable. Towards these ends we are greatly assisted by an interesting circumstance attending the outcrops of the strata. The softer beds of the Coal-measures have their edges turned down-hill in a remarkable manner. This feature, illustrated in various parts of the present work, is exhibited in Fig. 770. All the more pliable rocks, and those most susceptible of erosion, are either so bent at their outcrops as to conform to the slope of the hill-side, or if friable, their materials are dislodged and strewn down-hill in a tapering sheet, dwindling in thickness, and growing more and more comminuted, until they are lost in the debris of the adjoining strata. The coal, from its indestructible nature, its susceptibility to comminution, and its superior lightness, having been carried farther by the waters from the outcrops of the beds than the materials of the other deposits, the coal-hunter avails himself of this circumstance to test the presence of a bed of coal indicated by a hill-side bench, and to trace it to its true position. He commences by digging a narrow pit on the lower side of the terrace of the coal, extending 6 or 8 feet up and down the hill; and if at the depth of a few feet he encounters the smut or wash of the coal-seam, he infers from its degree of purity, and the average size of the lumps of coal, his distance approximately from the bed in place, and then plants his next pit where he supposes the top layer of the coal to outcrop. After two or three trials—and if he is experienced, sometimes upon his very first essay—he sinks directly through the outcrop of top slate into the soft disintegrated coal itself, the lamination of which he presently discovers. Persevering, he soon cuts the entire thickness of the coal, and reaches its floor or bottom-rock, and is then for the first time able to discover the true inclination of the bedding and the actual thickness of the coal-seam.

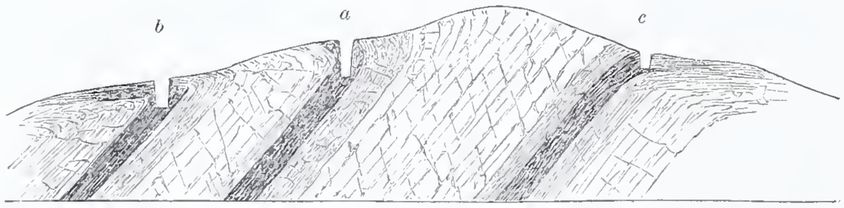


Fig. 770.—Overturned Outcrops of Coal-Seams.

Not unfrequently an intermediate trial-pit encounters the outcrop of the coal-bed just at the spot where it is folded abruptly down-hill. If the strata are themselves dipping in the direction of the hill-side slope, this folding is often very abrupt, and can then seldom lead to deception as to the true direction of dip; but in some instances, especially where the coal-bed is thick, and its capping rocks are not very pliable, the overturn at the outcrop is only partial, and the miner, after digging through the crumbled coal, reaches the bottom of its top slate dipping *towards* the outcrop. Unless he is very apt and persevering, he is liable in such cases to conceive that he has reached the genuine bottom rock of the coal-seam, and to suppose that this is dipping in just the contrary direction to that towards which it is declining.—(See the middle shaft *a*.) Not a few serious mistakes, and some flagrant frauds, in developing virgin coal-fields, have arisen from this substitution of a partially-overturned roof-rock for the genuine floor of a coal-bed.

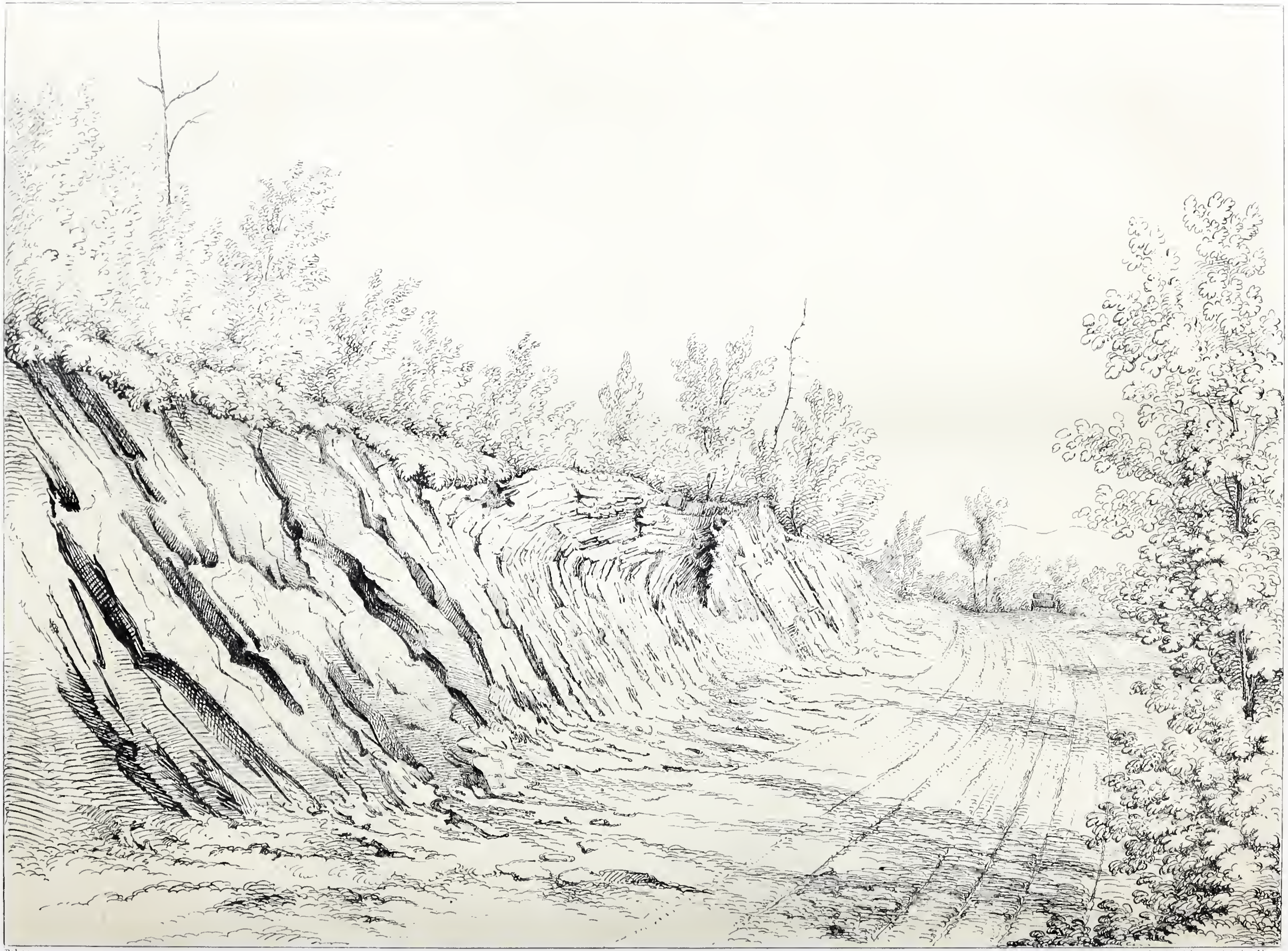
An uninitiated explorer sinking his experimental pit just within or above the turn of the cap rock or top slate of the coal, will be very apt, where the strata have a steep dip, to exaggerate grossly the real thickness of a coal-bed; for he may make a deep excavation before he reaches the bottom-slate, and if this should bulge forward into a flattish slope from a local irregularity, or turn into a gentle dip, self-deception is almost unavoidable. His true check to a blunder from this source is to mark narrowly as he proceeds the grain or lamination of the coal itself, which will betray in its direction and curvature the true dipping of the strata. Whenever it suggests a doubt, he should proceed, before sinking farther, to cut across the coal until he reaches one or both of the rocks which confine it, aiming by preference for the bottom shale.

Another source of fallacy, susceptible of being employed for fraudulently exaggerating the thickness of a coal-seam, is where the top slate of a steeply-dipping coal-bed, being tough and flexible, is turned or folded sharply back upon itself down the hill-side under the soil, as shown at *b*. If a large quantity of the outcrop coal lies over the inverted top-slate, the coal-digger may by chance or by adroitness so cut the coal at the bend as just to graze the knuckle of the folded slate, and make it appear as a layer or parting-band in the middle of the seam, especially as the grain of the coal

Dalson

Entered according to Act of Congress in the Year 1858 by Henry D Rogers in the Clerks Office of the District Court of the United States, in and for the Eastern District of Pennsylvania

COAL BENCHES. LOCUST M^T OPPOSITE LEHIGH SUMMIT MINES.



Dalston

W. & A. K. Johnston, Edinburgh.

OVERTURNED OUTCROP, NEAR NEWKIRK, PENN^A

both above it and below it will, by the inversion, dip towards the same quarter, and approximately at the same angle. The check for this is a very little excavation in the slate itself.

Where the strata dip into a hill, or towards an opposite point from that to which the ground itself is sloping, the outcrops of the softer beds are bent, as in the previous instances, to conform to the hill-side, but in this case they are not folded upon themselves, but only bent back into a flatter inclination, or into a gentle anticlinal curve. The wash of the coal-seam dips in an opposite direction from the coal-seam itself, and the friable shale or fire-clay floor is for the most part mingled with the fragmentary coal. Under this condition of things it rarely happens that either the coal or its top or bottom rocks are in a sufficiently regular or sound state to mislead us as to the direction of the dip; the only error to which we are liable being that of assuming too flat an inclination in the strata. The correction for this is to dig well into the coal, following the bottom-slate until it appears to assume its permanent inclination.

The two opposite conditions are represented in the cut at *b* and *c*, fig. 770.

Boring.—Another method of searching for coal is by boring. This is usually resorted to either where coal is suspected to underlie the soil at easily-accessible depths, or where it is desirable to ascertain the precise depth of a bed or beds already known to be present. In the one case a hand-augur with a shank 6 or 12 feet long is not unfrequently employed, and it is an extremely useful instrument in ground where the outcrop of the coal is not indicated by indentations of the surface, and is covered up by a shallow and easily-penetrated wash. In the other instance, where a known coal lies deep, and where it is important to ascertain its depth, and perhaps its thickness, prior to sinking a permanent pit or mine-shaft to it, boring is performed in a more elaborate manner, very much upon the plan of perforating an artesian well. A chisel of the requisite size is fastened to a stiff iron rod, and this is lifted and allowed to fall in repeated blows by some appropriate mechanism—either a lever worked by hand, or a trip arrangement driven by a steam-engine. As the boring deepens, the rod is lengthened by screwing upon it fresh sections several feet in length.

Great caution is to be observed in judging of the materials penetrated by this process. The materials chipped off by the chisel must be submitted to the closest scrutiny, carefully magnified by a lens, and moistened by an acid to ascertain the presence of any carbonate of lime or limestone. Care is especially necessary where the chisel indicates coal, for it not unfrequently happens that the crumbed coal already cut falls into the bore-hole by the friction of the rod, and mingling with the triturated particles of an underlying coal slate or shale, gives the appearance of an extension of the coal bed to a depth which it does not reach—a fertile source of unconscious error and of frauds. Nevertheless this plan of sounding for coal is a valuable auxiliary in the development of a new coal-field, as a guide to the sinking of deep and costly mine-shafts.

Opening or proving Coal-Seams preliminary to Mining.—The outcrop of a coal-seam having been discovered, the first step, preliminary to the erection of a colliery, is the determination of its thickness, quality, and the direction and condition of its dip within the strata.

When the coal-seam and its attendant rocks have a considerable inclination, the first steps towards proving are those hinted at under the previous head of "Surface Shafting." But prudence requires that the seam should be mined to some distance beyond that which is necessary merely to determine its presence and approximate thickness. It should be cut into far enough to let the miner see its permanent rate of dip; the absence or presence of any slips or faults, the quantity and distribution of its internal layers of slate, and of those soft laminæ which he calls "undermining," the lucky disposition of which affects not a little the economy of hewing the coal. If the coal-bed is somewhat unsound, or is "slippy" near its outcrop, but is yet of sufficient importance and promise to encourage the adventure, the miner will often enter it for many yards, either by horizontal gangway or by a sloping pit, withdrawing the water when necessary by a windlass or otherwise, in the hope that it may grow sounder.

Where the strata are horizontal, or nearly so, the difficulty of proving a newly-opened coal-seam almost vanishes, if the shape of the surface is such as to permit him to enter it at a relatively low level, and mine in the direction of its rise, for the mine gallery or drift will then drain itself; but if no ravine or hill-side exists to offer such approach, he must plan the course of his drift not directly down the dip, but as obliquely to it as practicable, with a view to the least possible amount of descent; and he must remove any water which collects, by digging a trench or drain in the floor of the drift, deepening the level of this from the mouth as he advances, until the task becomes too serious, when he must resort, as in the case of steeply-dipping coal-seams, to lifting or pumping the water out.

A case sometimes arises in which it is impossible to open a mine in horizontal strata which will drain itself, even though the outcrop of the coal-seam is surrounded by ravines or valleys on all sides. This condition prevails where, with a stratification almost absolutely horizontal, on a broad scale, the country is intersected by deep ravines, and the hills insulated by these are lofty and steep. In such ground it sometimes happens that the coal-seams basin inwards from all points with a very gentle descent under the summit of the conical hills, as if the increased pressure there exercised by the superior column of the strata had caused a general dishing of all the more compressible and pliable members of the series. In such cases there is no mode of draining the mine but by a trench under the floor of the gangway, or by a regular mine-shaft sunk into the middle of the basin, from somewhere near the summit of the hill or centre of the plateau.

METHODS OF MINING COAL.

In the coal-fields characterised by an approximately horizontal stratification, the plan of mining the coal in Pennsylvania, and indeed throughout the United States, is that which is pursued under similar circumstances in Europe. The coal-seam is entered by a main gangway or nearly horizontal gallery, so placed and laid out as to drain as large a tract of the contemplated mine as possible.—(See Fig. 771.) If the coal-seam is situated above the beds of the adjacent valleys, it is penetrated, of course, from a point or points in the sides of the hills, and a thick wall or pillar of the coal is left between the gangway and the actual outcrop, to sustain the pressure of the superincumbent strata. After the main entry has been carried in a convenient length, other side-galleries or gangways are excavated, branching from it, either at right angles, or in directions best adapted to command an easy drainage and internal transportation of the hewn coal. From these lateral alleys short rooms or stalls are excavated, leaving massive columns of the coal standing to support the roof.

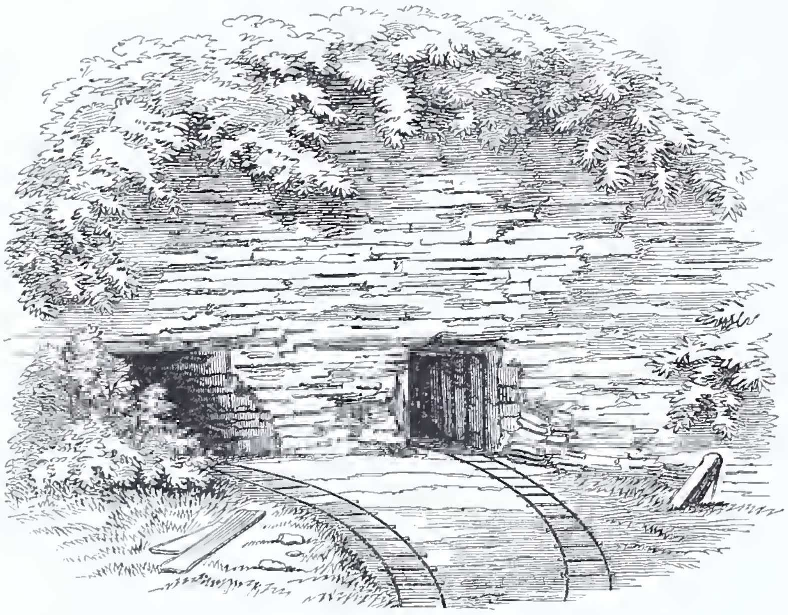


Fig. 771.—Mouth of Drift in Horizontal Strata.

In the anthracite basins of the State, where the strata are much undulated, and where, for the most part, they are inclined at considerable angles, the plan of entering and mining the coal is somewhat different, being modified to suit the circumstances.

Open Cut.—The simplest of the conditions under which coal is excavated in the State is where it lies accessible to open quarrying. This method is resorted to only where the coal-bed is of such thickness, or has been so effectually protected from deterioration by a covering of easily-removable rock, as to possess a marketable value. Of course it is seldom worth while to strip and quarry a thinnish seam of coal, since the coal itself will be found rotted by the elements throughout too great a portion of its thickness, and even where sufficiently sound, will not yield enough to a given area to repay the cost of uncovering it. Perhaps the most remarkable example of a coal-working in the manner of an open quarry, to be anywhere met with, is that of the Lehigh Summit Mine, already described.—(See the plates illustrating this mine.) Another form of open working is, where a thick seam of coal has been caught, and preserved from denudation from a sharp synclinal fold in the strata. An instance of this sort occurs at Montelius's Open Cut, at the E. end of the Mine Hill Valley, opposite the mouth of Wolf Creek, where the great coal-seam, folded into a V-shaped mass, is entered endwise, and quarried out from between the steeply-dipping sides of the trough, composed of its bottom-slate. The excavation is about 50 feet deep, and nearly as broad at the top. The annexed cut (Fig. 772), represents this quarry of coal as it appeared in 1853.

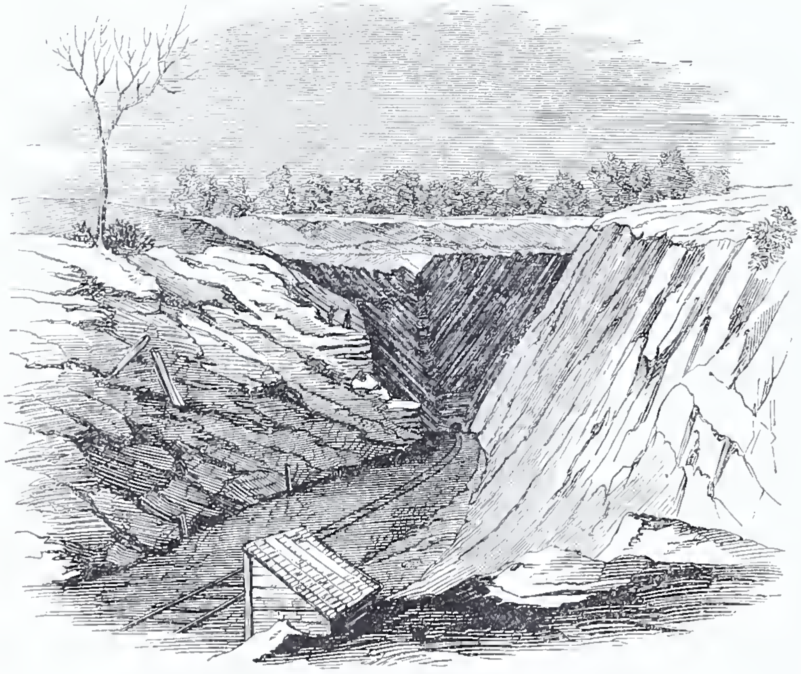
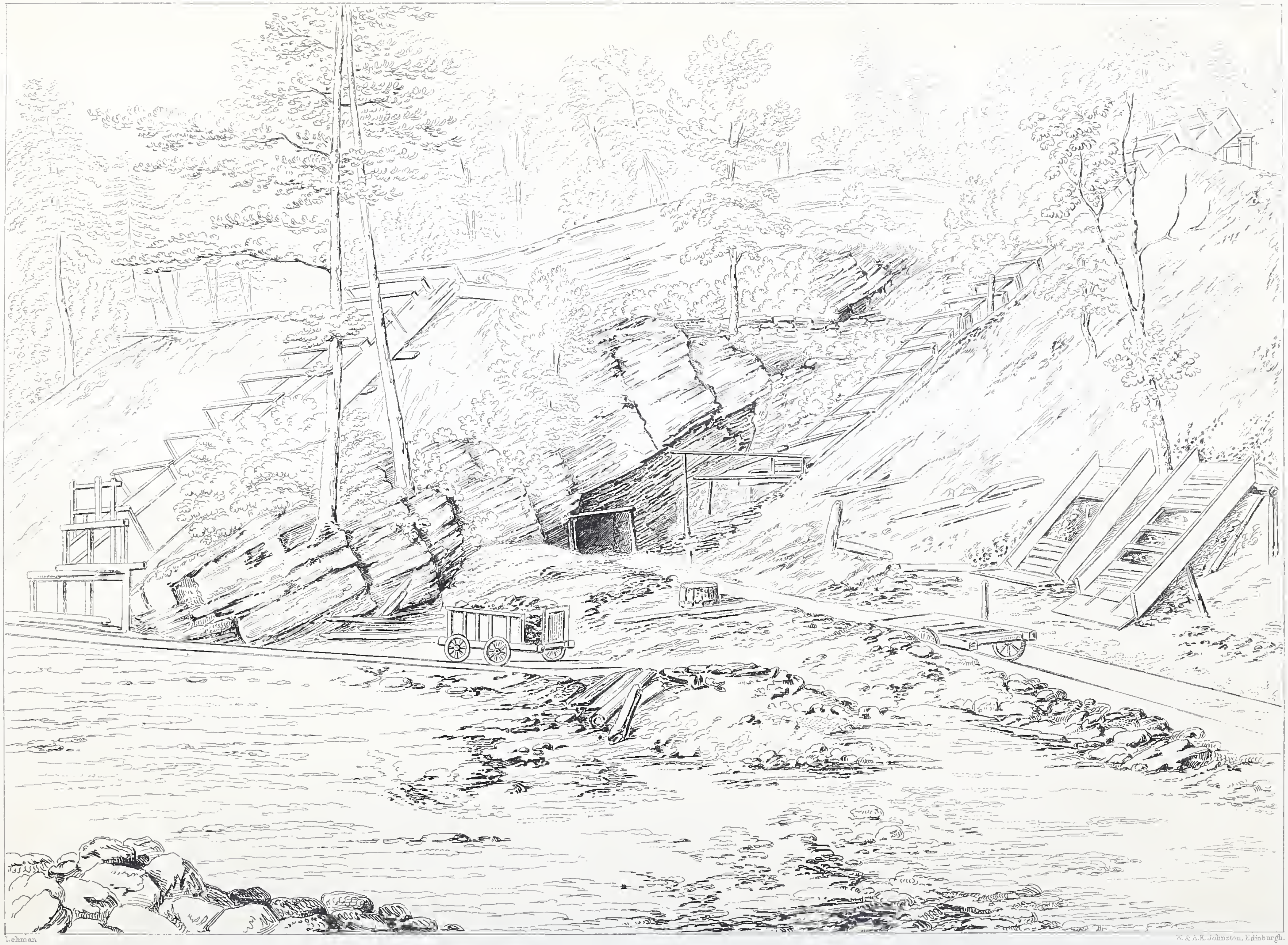


Fig. 772.—Montelius's Open Cut, Mill Creek, Mine Hill Valley.

Another extemporaneous process of mining is resorted to where the coal-seam is approximately horizontal, and outcrops on both sides of a comparatively narrow hill. The field of coal is then entered from some ravine near the most depressed part of the outcrop, and the coal is mined out in the direction of the rise of the strata, by leaving huge columns of the solid coal to sustain the weight of the hill above. Where the seam is thick, the subterranean quarrying proceeds by benching, or cutting the coal in steps. An extensive excavation of this sort is to be seen at the old mines of the Baltimore Coal Company, about one mile S.E. of Wilkesbarre. The frontispiece to this volume presents one view of the exterior of this mine. An interior view, looking outward, showing the massive columns of coal, and the twilight between the pillars, is shown in another sketch (see Plate, p. 382 of this volume).

By Drift.—A common method of mining hitherto practised in the anthracite basins of the State, has been to select



Lehman

W. & A.K. Johnston, Edinburgh.

The 14 ft. Seam., NESQUEHONING MINES., *Old drift, Shutes & Screens.*

a locality where a coal-seam rises to a remunerative height above some convenient water-level, or the bed of a contiguous valley or ravine intersecting it. The seam is in this case accessible edgewise or endwise from the ravine, and after the surface-matter is removed, it is entered by a *drift* or gangway, which is carried in horizontally, with just a sufficiently gentle rate of ascent to drain out the water to the external valley. After this mine "level," as it is called, has been extended sufficiently far, lateral alleys or schutes are cut at a convenient angle, usually at right angles to it, ascending towards the outcrop, and rooms or small chambers are hewn out of the coal at regular intervals along these alleys, pillars of the firm coal being left between these chambers, and also between them and the schute, except where this communicates with the rooms. Thus each schute is protected by a wall of solid coal, only here and there perforated. Certain of these schutes are extended up to the outcrop as early as practicable, for the purpose of ventilating the workings, the air in which tends to become very foul where the dip is steep, and the "breast" or slant length of the coal-bed is tall. The coal is shovelled by the miners from the lateral chambers into the sloping schutes, and is drawn out of these from an inclined bin by gates or trap-doors, which deliver it into the coal-cars placed opposite them on a railroad which occupies the floor of the main horizontal gangway.

Another mode of carrying on the excavation of the coal in the interior of the mine is, to take it out in broad rooms, still called schutes, extending from the level or gangway up the breast of the coal to within a suitable distance of the next higher level, or of the outcrop, leaving longitudinal pillars or walls of the solid coal strong enough to support the pressure of the superincumbent mass. These pillars are generally from 4 to 8 yards wide, and the long rooms or schutes between them are commonly from 10 to 14 yards broad. Just at the gangway the pillars are generally left as broad as possible, the better to insure resistance to pressure, and for the purpose of more easily closing the outlet of the schute, and providing it with a gate for the delivery of the coal into the cars below. In some cases, especially where the dip is steep, a narrow schute, called a "man-way," is first cut, ascending the breast, and cross-ways are excavated from this to give the miners an opportunity to cut or blast away the coal from the breast above them. These lateral excavations, enlarging and meeting, form the schutes into which all the coal is collected. When the process is completed, the only coal left standing to support the roof is in a series of pillars or columns perforated by the man-way.

The accompanying cut (Fig. 773), exhibits the workings of a colliery in the Pottsville Basin, where the features are somewhat complicated. It is intended to represent the areas from which the coal has been extracted, and those where it has been left standing for the support of the mine; or where, being too unsound, it would not repay the cost of mining. It is a ground plan or view of the mine as seen from above, showing in the coarse dotted lines an anticlinal axis, and a synclinal axis in the strata, and in the finely-dotted ones the boundaries of the crushed coal not worked. It also shows the gangways, and the tunnels driven through the strata to connect them, and also the pillars and intervening schutes or rooms.

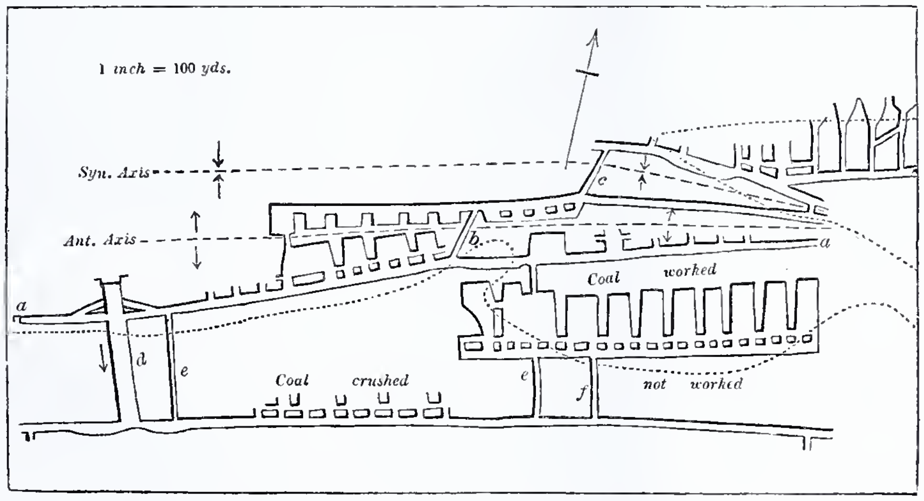


FIG. 773.—Part of Underground Workings of the Primrose Coal-Seam at Neill's Colliery on Silver Creek, from a Plan by G. K. Smith, Mining Engineer of Pottsville.

a a, Drift or Gangway at Water Level.
b, Tunnel across Anticlinal to Coal on N. dip.
c, Tunnel across Synclinal to Coal on S. dip.
d, Slope or Inclined Roadway to Lower-Level Gangway.
e, Air-ways communicating with Water-Level Gangway.
f, Counter-Schute from Counter-Level Gangway.

By Tunnels.—Another and very common mode of reaching the coal, particularly in the steeper-dipping beds of the anthracite basins, is by tunnels cut across the strata, the slates, sandstones, &c. which separate the seams of coal. These tunnels are often resorted to, to get admission to portions of coal-seams which ascend into the hills and outcrop above the levels of the valleys and ravines. In such cases they are designed to give outlet to the coal, and to drain the mines, very much as the gangways do which enter the coal-seams endwise from intersecting ravines. The best level at which the tunnel should be made often requires a nice calculation between the cost involved in lengthening it, by planting it too low, and the sacrifice of losing available coal, by making it shorter and setting it too high. Where the coal-seams occur at comparatively short intervals in the strata, and where their dip is steep, a tunnel of the length of a few hundred yards, made at a moderate outlay of capital, will intersect and develop for mining several valuable coal-seams. These are mined in the usual mode, by gangways cut right and left from the tunnel, which thus becomes the common outlet for all the coal of the several seams which it intersects. It is therefore not unfrequently constructed broad enough to admit two railway-tracks, to facilitate the passing of the coal-cars in and out of the mines.

Such are the tunnels which penetrate the hills of the coal region from the surface ; but these transverse excavations are much resorted to for getting access to portions of the coal-seams which lie below the beds of the valleys, and which are not directly reachable by the slopes already sunk. Not unfrequently it is an object for the collier to extract the coal from a seam, the position and value of which he is aware of, without constructing a new slope upon its outcrop, and replanting his machinery. In such a case his course is a very simple one : he selects some wide and suitable place in one of the gangways already communicating with the slope, and cuts a horizontal tunnel directly across the strata to the otherwise inaccessible coal. Reaching this seam, he develops it by a new gangway, and proceeds to mine it like the other. Sometimes these subterranean tunnels start forward or backward at the foot of the slope to intersect the overlying or underlying coal-seams, but frequently they extend from the gangways of the mine. As the mining deepens in the bed containing the slope, it may be deepened in the adjacent auxiliary seams by the construction of these short underground tunnels.

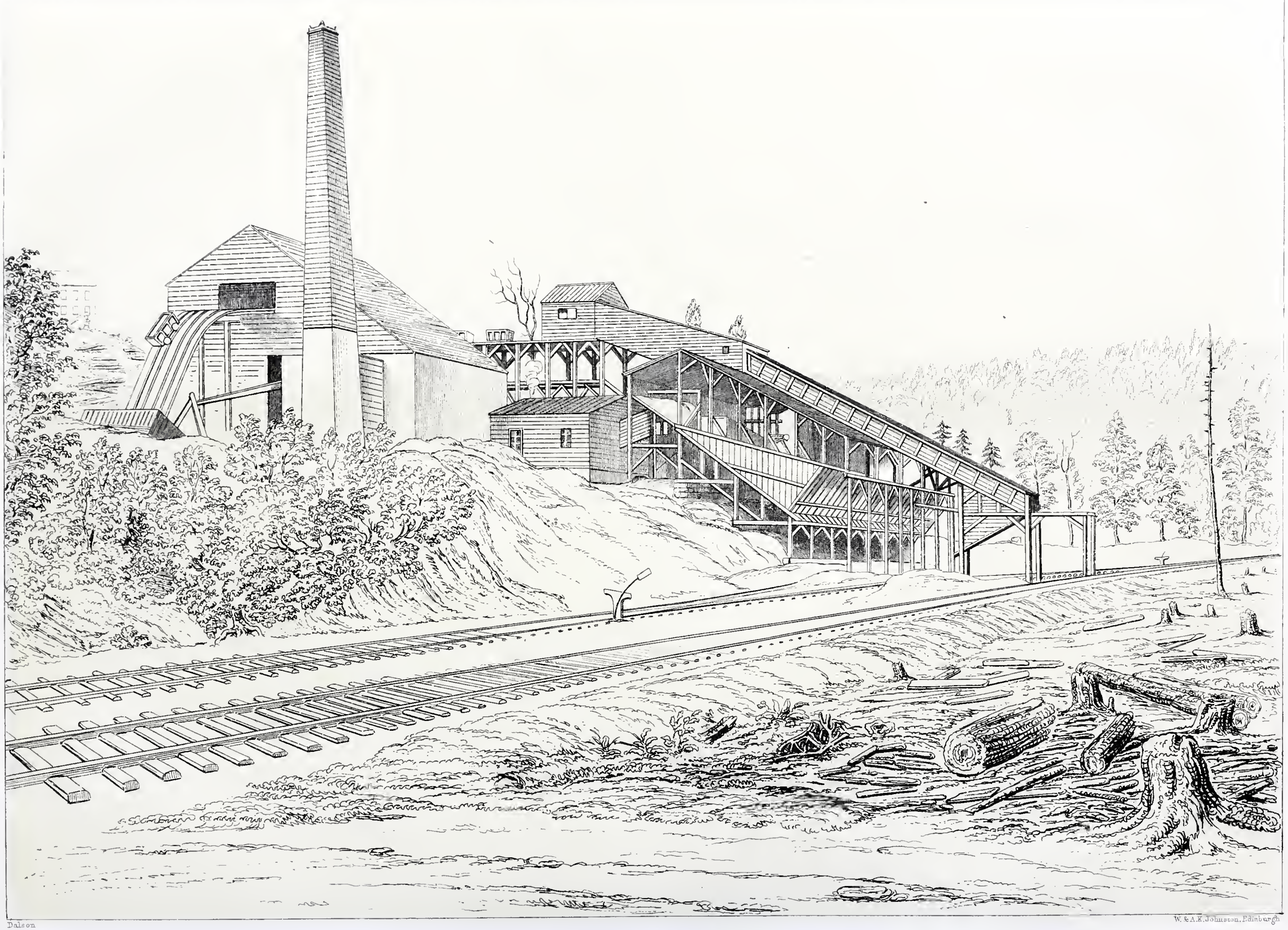
By Slope.—Other modes of entering the coal are necessary where it lies below the water-levels of the country, or where the portion above the valleys and ravines is insufficient to justify the erection of a colliery. The mode commonly resorted to in the anthracite region, is to enter the coal-seam by what is called a *slope*, or a broad gallery hewn in the coal in the direction of its dip ; this gallery is usually wide enough to contain two railroad tracks, one for the down-going, the other for the up-coming coal-cars of the mine. The machinery, a steam-engine of competent strength, is planted a little back from the mouth of this slanting tunnel, and the cars are drawn up or let down by a chain wound upon a large drum. In mining the coal, a level or horizontal gangway, such as that already described, is cut at right angles, leading off in one or both directions from the bottom of the slope, with such a departure from absolute horizontality as to allow the water to collect at the intersection. A well, called a " sump " of the mine, is sunk at this spot, the foot of the slope, and a pump usually formed of segments of iron pipe of large calibre extends from this sump to the mouth of the slope, or to some previously-opened water-level or adit-tunnel passing the pump-water to the outside of the mine. From each level or horizontal gangway schutes are extended upwards through the coal, and the coal is mined from them in the ways above described ; and when it is all withdrawn from the field thus opened, the slope is prolonged a convenient distance downwards, usually from 60 to 100 yards, dependent upon circumstances ; a new sump is planted, and another gangway or level is cut parallel to the upper one. In mining the second lower breast of coal insulated between the two levels, the schutes extended upward from the lower level open into the upper one, and thus a more effectual ventilation of the interior of the mine is insured ; and as the mining advances, and the slope increases in length, new levels are set off, and new breasts are wrought out, until the bottom of the basin is reached, or the lift becomes too great for the machinery. In mining the coal, care is observed to leave untouched a broad column or wall of the coal standing along both sides of the slope, as any crushing-in of this from insufficiency of support would be fatal to the operations of the mine.

INTRODUCTION OF COAL AS A DOMESTIC FUEL.

Notwithstanding the immense accumulation of carbonaceous matter in the earlier strata of the earth's crust, its general use as a domestic fuel, and for the purposes of the arts and manufactures, would appear to have been reserved for very modern times. That fossil coal was known as a casual mineral, and partially used as a combustible matter by the ancients, appears from the writings of Theophrastus, the disciple of Aristotle, for undoubtedly the word λιθανθϱαξ, used by the Greeks, signified fossil or pit coals, in contradistinction to ανθϱαξ, charcoal, or wood-coal. Theophrastus, in his *Book on Stones*, says, " Those fossil substances that are called coals, and are broken for use, are *earthy ;* they kindle and burn like *wood-coals*. These are found in Liguria, where there is also amber ; and in Elis, in the way to Olympias, over the mountains. They are used by the smiths."

A Roman writer, Siculus Flaccus, mentions that coals, among other substances, were made use of as landmarks ; and St Augustine mentions the same, remarking that this substance was so used on account of its imperishable nature—the carbon of hard coals no doubt resisting moisture and decay better than wood or soft stony materials. It seems evident, however, that the ancients made no extensive use of fossil coal, much less mined for it, but only casually employed such fragments as were found on the surface of the soil. The comparative rarity of this material in Greece, Italy, and in ancient Egypt, was perhaps the chief reason of its escaping the inquisitive eyes of those early civilised nations.

In the earlier stages of the civilisation of tribes and nations, and in countries but yet partially cultivated, and still abounding in natural woods, the most accessible and easily-procured fuel, as wood, peat, and superficial lignites, would be resorted to ; and these, we find, constituted the chief articles employed as fuel in the early periods of the history of Western Europe. It is probable that the aborigines of Britain knew something of coal, and used it partially. The term *kul* or *kole* is of Saxon origin, used primarily to signify any substances capable of ignition as fuel ; while *kolom* is the Cornish, and *guel* the Irish name for similar substances. It seems evident, too, that the superficial coal strata of Britain did not altogether escape the penetrating eyes of the Romans. From coal-cinders found in various localities



Dalson

W. & A.K. Johnston, Edinburgh

COLLIERY SLOPE, AND BREAKER, AT TUSCANORA.

associated with Roman coins, and other indications of the domestic establishments of this people, there appears no doubt but that fossil fuel was partially used by them while in Britain.

In A.D. 853, the Saxons, then dominant in England, were familiar with the use of pit coal, for in a grant of land made by the Abbey of Peterborough, among other reservations of certain fragments of goods in kind, is mentioned "sixty cart-loads of wood, and *twelve of fossil or pit coal.*"

In the *Bolden Book*, a record of the county of Durham, we find, A.D. 1195, that among the allowances to the tenants in villenage at Bishopwearmouth, "the smith has twelve acres for the iron-work of the carts, and finds his own coal" (*carbonum*).

In A.D. 1239, King Henry III. granted the privilege of digging coals to the "good men" of Newcastle, in the vicinity of that place; and this is perhaps the earliest notice we have of the actual working of coals.

In some additions to Matthew Paris's *History*, dated A.D. 1245, we have the term sea-coal (*carbo maris*) mentioned,—evidently showing that about this period coal was not only dug from pits for consumption in the locality, but also exported, or sent by sea, to other parts of the kingdom. There is also here mention made of the winning of coal of pits, and the wages paid to the men who wrought in them. From an account-book of the servants of the Archbishop of Canterbury during the reign of Edward II., we find that thirty cart-loads of coal were transported from Barston to Croydon, probably for the Archbishop's special use, as wood was then abundant and very cheap in the neighbourhood of his residence.

In Scotland, previous to the twelfth century, "wood, turf, and peat," and other articles of fuel, were subjected to legislative arrangements, but no mention is made of coal,—the earliest notice of the use of this substance being A.D. 1291, when the privilege of digging coal in the county of Fife was granted to the Abbey of Dunfermline. Long after this, Æneas Silvius, afterwards Pope Pius II., in his visit to Scotland about the middle of the fifteenth century, relates, as something novel to him, that he saw poor people in rags begging at the churches, and receiving for alms pieces of stone, with which they went away contented. "This species of stone," says he, "whether with sulphur or whatever inflammable substance it may be impregnated, they burn in place of wood, of which their country is destitute."

Towards the close of the thirteenth century, so rapidly had the use of coal extended, that the coal trade of Newcastle, then, as long afterwards, the great centre of the supply, became an object of considerable importance to the burgesses—so much so, that had not that town been granted before by King John at a fee-farm of one hundred pounds per annum, payable to the Crown, that sum would probably at least have been doubled to the then existing burgesses.

The early workings were no doubt of the simplest and rudest kind; nor for a long period had the deeper and best seams of coal been reached; for we find, from the *Household Book* of the fifth Earl of Northumberland, A.D. 1512, that though coals were largely used in his princely establishment, it was only in conjunction with wood, "because," it is observed, "colys will not byrne without wodd." It is here stated that eighty chaldrons of sea-coal, at 4s. 2d. and 5s. the chaldron, were allowed in the year, and also sixty-four loads of great wood, to make the coals burn. During the fourteenth and fifteenth centuries, the use of pit-coal as fuel gradually increased, especially as there had been a wasteful consumption of wood in the country, and a neglect in planting forest trees, so that wood for the purposes of fuel became very scarce and expensive.

The use of coal in the cities, however, was at first met by that popular and ignorant prejudice which assails all innovations of the kind upon ancient use and wont. In the reign of Edward I., the inhabitants of London loudly protested against the growing use of sea-coal; and in a proclamation of that monarch, A.D. 1306, the use of sea-coal is expressly prohibited in London and the suburbs, on account of its sulphurous smoke and smell, and all persons are enjoined to burn wood.

Even in the reign of Elizabeth, the burning of "stone coal" was prohibited in London during the sitting of Parliament, lest the health of the knights of the shires should suffer during their residence in town.

In 1649, Blythe, an agricultural writer, says—"Not many years since, the famous city of London petitioned Parliament against two nuisances or offensive commodities, which were likely to come into great use and esteem; and that was Newcastle coals, in regard to the stench; and hops, in regard they would spoyle the taste of drink, and endanger the health of the people."

Notwithstanding these popular prejudices and royal proclamations, the consumption of pit-coal still increased; and as more convenient modes of burning it in houses were invented, its "smoke and stench" were greatly abated, till by degrees it gradually began to supersede the use of wood. Other obstacles, however, still impeded its progress as a cheap fuel to the people, such as import duties, and monopolies shamefully abused; so that in 1648 fuel of all kinds was so scarce in the metropolis that many poor people were starved to death. Little more than three centuries ago, two ships were sufficient for the whole coal-trade between Newcastle and London. In 1699, Newcastle had two-thirds of the coal-trade, and 300,000 tons were exported to London. The price was 18s. per chaldron, out of which 5s. were paid as king's duty. In 1845, the same city had an annual importation of 3,403,000 tons, and in 1854, 4,386,971 tons.

As the consumption of coal increased, so also did the spirit for mining; and a writer towards the close of the seventeenth century thus describes the state of mining speculations in the northern counties:—"Many thousand people are employed in this trade of coals; many live by working of them in the pits; many live by conveying them in waggons and wains to the river Tyne. Many men are employed in conveying the coals in keels from the stathes aboard the ships. One coal-merchant employed five hundred or a thousand men in his work of coals, yet for all his labour, care, and cost, can scarce live of his trade; nay, many of them hath consumed and spent great estates. Some south-country gentlemen have, upon great hope of benefit, come into this country to hazard their monies in coal-pits. Master Beaumont, a gentleman of great ingenuity and rare parts, adventured into our mines with his thirty thousand pounds, who brought with him many rare engines not known then in these parts—as the art to bore with iron rods, to try the deepness and thickness of the coal; rare engines to draw water out of the pits; waggons with one horse to carry down coals from the pits to the stathes, and to the river. Within few years he consumed all his money, and rode home upon his light horse." *

On the continent of Europe the use of pit-coal is also comparatively of modern date. We have seen that in the middle of the fifteenth century an Italian traveller of rank and intelligence, Æneas Silvius, when he saw pieces of coal distributed to the poor in Scotland, appeared to be wholly unacquainted even with the aspect and general nature of the substance.

Coal strata are by no means abundant on the European continent, and France first obtained its knowledge of this mineral from Britain.

In the year 1520, coals imported from Newcastle were first used in Paris, and the same prejudice against them existed as in London, so that their employment as fuel was very limited.

In Belgium, pieces of coal, obtained from seams that had cropped out to the surface in the vicinity of Liege, were used as fuel by a blacksmith † as early as A.D. 1200, and from this period coal gradually came into use in that country.

About the middle of the sixteenth century, coal-mining began to be practised in France; and in the eighteenth century, coal-mines were commenced in the basins of the Loire, Brassac, and Decize.

The use of coal and coke in the smelting of iron forms another important step in the progress of coal-raising. In the reign of James I., wood charcoal was employed in the very limited smelting-foundries for the production of iron, which then existed in Britain; and in France, down to a much later period, about one-fourth of the wood used for fuel was consumed in metallurgic processes.

It was in 1740 that the celebrated ironworks were established at Colebrookdale in Shropshire, in which coke produced from pit-coal was successfully used. Many previous trials had been made, and many failures and disappointments arisen, chiefly from the imperfect manner in which the coke had been prepared; but after this period the smelting of iron began gradually to extend in Britain; and as from five to six tons of coal are required to produce one ton of iron, the consumption of coal in this process became in the course of time very considerable. By a fortunate arrangement in nature, the same strata which yield coal also produce the kinds of iron ore from which the metal is most readily extracted; and thus the coal districts of Britain, abounding in both materials, now produce more than a half the whole iron of the world.

The introduction of the hot-blast process in the smelting furnaces, the invention of Mr Nelson in 1828, by facilitating the production of the metal, and especially by permitting the use of anthracite coal, has greatly extended the manufacture both in Britain and America.

The manufacture of glass was also greatly facilitated and extended by the use of coal-coke as a fuel for the furnaces. Though this manufacture was introduced into Britain as early as A.D. 674, and a manufacture of the finer kinds was established in London in 1557, yet it was not till 1619 that an extensive manufactory of all kinds of glass was commenced on the banks of the Tyne, and in the centre of the great Newcastle coal-field, which still continues to flourish, while extensive glass and pottery manufactories have since sprung up in Staffordshire and other coal districts of Britain.

But the most wonderful and beautiful, as well as one of the most important uses to which coal was put, was that of the production of carburetted hydrogen gas for the purposes of illumination. At first, perhaps, indicated by natural gaseous exhalations from the earth, in India, Persia, and North America, where the natives were accustomed to apply hollow reeds, and form the gas into jets of flame—it was subsequently investigated by chemists; but the merit of practically applying it for the purpose of domestic illumination appears due first to Mr Murdoch, who in 1798 constructed an apparatus for its production and use in the Soho Foundry, Ayrshire, Scotland; and secondly to Mr Windsor, who in the years 1803 and 1804 publicly exhibited gas illumination in the Lyceum Theatre, London.

If we add to all these the employment of coal in the production of steam-power, now used in almost every manufactory of whatever description, as well as its extensive use in locomotive engines on land and sea, we shall immediately perceive that this mineral, so abundantly stored up in the earth's strata, yet so long left to repose in utter neglect, has now become the most powerful and universal agent of modern civilisation.

---

* GREY'S *Chronographia.*

† The name of this blacksmith was Hullos de Plennevaux; hence is said to be derived the now common name of *houille* for mineral carbon or coal.

AMERICAN AND EUROPEAN COAL-FIELDS.

ACTUAL AND RELATIVE AREAS—THICKNESS AND AMOUNT OF COAL IN THEM—AND PRESENT ANNUAL PRODUCT OF THEIR MINES.

Forming a summary estimate of the extent of the productive coal-formation of the United States, as presented in pp. 758 and 942-968 of this volume, for the sake of a comparison with the coal resources of other countries, we find that the E. half of the continent exhibits five great coal-fields, extending from Newfoundland to Arkansas. 1. The first, or most Eastern, is that of the British provinces, Newfoundland, Nova Scotia, Cape Breton, Prince Edward's Island, and New Brunswick. This seems to have been originally one wide coal-field, subsequently broken up into patches by upheaval and denudation, and by the submergence which formed the Gulf of St Lawrence. The area of the Coal-measures of the provinces is probably about 7500 square miles, though not more than about one-eighth of this surface appears to be underlaid by productive coal-seams. 2. The second, or great Appalachian coal-field, extends from North-eastern Pennsylvania to near Tuscaloosa, in the interior of Alabama. It is about 875 miles long, and 180 broad, where widest in Pennsylvania and Ohio, and by a careful estimate contains about 56,000 square miles. The narrow basins of anthracite in Eastern Pennsylvania, containing more than 400 square miles of coal, are outlying troughs from this great coal-field. 3. A third smaller coal-field occupies the centre of the State of Michigan, equidistant from Lake Huron and Michigan; it covers an area of about 13,300 square miles, but it is very poor in coal. 4. A fourth great coal-field is that situated between the Ohio and Mississippi anticlinals, in the States of Kentucky, Indiana, and Illinois. It has the form of a wide elliptical basin. It is about 370 miles long and 200 miles wide, and contains by estimation 51,000 square miles of Coal-measures. 5. The fifth, and most Western, is the large and very long coal-field filling the centre of the great basin of carboniferous rocks which spreads from the Mississippi and Ozark anticlinals W. to the limit of the Palæozoic region, where the cretaceous strata begin. The coal-field itself has its N. limit on the Iowa River, and its S. in the Indiana territory, near the Red River, to the W. of Arkansas. It is in length 650 miles, and in greatest breadth 200 miles. The total area of this great irregular basin is probably not less than 74,000 square miles. Three or more small detached tracts of coal strata, encompassed by the cretaceous deposits, stretch at intervals S.W. from the S. limit of the longer field through Texas. They are probably extensions of the great field laid bare by denudation. Their extent is imperfectly known, but my Geological Map, constructed from the best documents, indicates an area of about 3000 square miles. Other localities of coal-bearing strata occur in the high table-lands on both sides of the Rocky Mountains, and also in the Wahsatch chain of Utah, but it is doubtful whether some of them belong to the true Carboniferous series. The aggregate space underlaid by these vast fields of coal amounts to nearly 200,000 square miles, or to more than twenty times the area which includes all the known coal-deposits of Europe, or indeed of the whole Eastern continent.

Comparing the areas of the coal-fields of other countries with those of North America now indicated, Great Britain may be estimated to contain about 5400 square miles, France nearly 1000, and Belgium 510 square miles. Rhenish Prussia—Saarbrook field—has 960 square miles, Westphalia 380, the Bohemian field about 400; that of Saxony only 30; that of the Asturias, in Spain, probably 200; and that of Russia, scarcely 100 square miles. And as these are the principal known coal-fields in Europe, the whole region is thus seen to possess less than 9000 square miles of productive Coal-measures. Comparing the coal areas with the total areas of the respective countries, the United States has one square mile of coal-field to each 15 square miles of its 3,000,000 miles of territory; Great Britain has one square mile to each 22½ of surface; Belgium a like proportion with Great Britain; while France possesses only one square mile of coal-field to every 200 miles of country. Assuming the total area of the productive Coal-measures of the world at 220,000 square miles, and accepting 20 feet as the average thickness of the available coal, the entire quantity, if estimated as one lump, is equivalent to a cube of very nearly 10 miles linear dimensions, or to a square cake or plateau of coal 100 miles broad in its base, and more than 500 feet high.

AREAS OF COAL-FIELDS.

NORTH AMERICA.

United States.

	Square Miles.	Length.	Maximum Breadth.
Appalachian Basin, .	55,500	875	180
Illinois, Indiana, and Kentucky basins, .	51,100	370	200
Missouri and Arkansas Basins, . .	73,913	550	200
Michigan, . .	13,350	160	125
Texas, . .	3,000		
	196,850		

British Provinces.

	Square Miles.
Newfoundland, ...	100 (?)
Cape Breton, ...	200
Pictou, ...	350
Cumberland, ...	200
New Brunswick (only a small part productive),	6689
	7530

EUROPE.

Britain,	5400 square miles.	Bohemia,	400 (?) square miles.
France,	984 ,,	Saxony,	30 ,,
Belgium,	510 ,,	Spain,	200 (?) ,,
Saarbrook field,	960 ,,	Russia,	100 ,,
Westphalia,	380 ,,		
		Total,	8964 ,,

AREAS OF THE BRITISH COAL-FIELDS.

Ireland,	200 square miles.	Dudley,	30 square miles.
Scotland—about	1500 ,,	Forest of Dean,	30 ,,
Durham,	750 ,,	Bristol and Somerset,	50 ,,
Cumberland,	100 ,,	Flintshire,	100 ,,
Lancashire,	500 ,,	South Wales,	1000 ,,
North Stafford,	100 ,,		
Great Central,	900 ,,	Total,	5400 ,,
South Stafford,	140 ,,		

EXTENT OF COAL-FIELD IN THE SEVERAL STATES POSSESSING THE COAL-FORMATION.

Massachusetts and Rhode Island,	100 (?) square miles.	Michigan,	13,350 square miles.
Pennsylvania,	12,656 ,,	Iowa,	24,000 ,,
Ohio,	7100 ,,	Missouri,	21,329 ,,
Maryland,	550 ,,	Nebraska,	3712 ,,
Virginia,	15,900 ,,	Kansas,	11,880 ,,
Kentucky,	13,700 ,,	Arkansas,	12,597 ,,
Tennessee,	3700 ,,	Indian Territory,	10,395 ,,
Alabama,	6130 ,,	Texas,	2,970 ,,
Georgia,	170 ,,		
Indiana,	6700 ,,	Total,	196,939 ,,
Illinois,	40,000 ,,		

The number of the workable coal-seams in the anthracite basins of Pennsylvania varies from two or three up to twenty-five, according to the depth of the basin; perhaps the *average* number, estimated for the entire surface, may be about ten or twelve.

It is not so easy to calculate the thickness of the coal itself, which varies ceaselessly with the depth of the erosion which the Coal-measures have suffered, from that of the thinnest workable bed to a computed maximum, in the widest and deepest parts of the Pottsville Basin, of 207 feet. I think it probable, taking the carefully-computed aggregate thickness of the workable coal-beds of the best-developed localities as the basis of my estimates, that the S. anthracite field possesses an average thickness, rejecting the thin seams, of 100 feet, the middle field a thickness of somewhere about 60 feet, and the N. field perhaps an approximate thickness of 60 feet also; while the general average for the whole anthracite region is not far from 70 feet.

The great Appalachian coal-field evidently lays claim to a materially less total thickness of coal, for the aggregate depth of all the workable seams in Western Pennsylvania, Western Virginia, and Eastern Ohio, where the basin is deepest, and the number of beds is fifteen or sixteen, scarcely amounts to 40 feet. Keeping in view the wide areas from off which the upper Coal-measures, and even a portion of the lower, have been denuded, we are hardly entitled to assume a higher general average for the entire coal-field than 25 feet.

Advancing W., the next great basin—that of Illinois, Indiana, and Western Kentucky—containing, as already shown, sixteen or seventeen workable beds in the last-named State, possesses a maximum thickness of workable coal of about 50 feet, and an average amount of perhaps 20 or 25 feet.

The third great coal-field—or that of Iowa, Missouri, and Arkansas—with a much thinner body of Coal-measures, appears nowhere to have more than two or three profitable coal-beds, and a total thickness of workable coal not exceeding 10 (?) feet. The average for the whole area is obviously materially less than this.

In estimating the average or mean thickness of the coal, due attention is paid, of course, to the deductions from the maximum amount, made necessary by unproductive areas, caused by denudation near the edges of the coal-fields, by deep erosion in the valleys, and by a crushed condition of the strata.

A comparison of the above estimates with the computed aggregate depths of workable coal in some of the British Coal-measures, will enable the reader better to appreciate the relative average value per acre of the American coal-fields with the best-explored European ones.

It is stated that the great coal-field of South Wales embraces twenty-three workable beds, having an aggregate thickness of 92 feet; but the *average* thickness for the whole basin is materially less than this—probably not exceeding 60 feet.

In the *South Staffordshire Basin* the coal amounts to a thickness of about 57 feet, and in one quarter to 70 feet. We may assume 40 feet as the average for the whole coal-field.

In the *Derbyshire Coal-field* there are about twenty workable beds, with an aggregate thickness of 60 feet, and an average for the whole area of 40 feet.

The *Lancashire and Cheshire Coal-field*, contains in one district 150 feet of coal in seventy-five beds, and in another 93 feet in thirty-six beds, but some of these are too thin to mine, and therefore these aggregates express more than is actually procurable. Probably the average thickness of workable coal for the entire coal-field amounts to 50 or 60 feet.

The *Durham and Newcastle Coal-field* contains a total thickness of 60 feet of coal, but the workable seams amount to only 30 feet, and the mean thickness of available coal for the whole tract does not probably exceed 20 feet.

In the *Lanarkshire Coal-field* there are nine workable seams, embracing an aggregate thickness of 37 feet, but the average for the whole area is of course less—perhaps it does not exceed 25 feet.

From these and other similar data, multiplying the areas of the coal-fields by the thicknesses of their productive coal respectively, adding the products, and dividing by the total area, I am led to infer that the general average thickness of procurable coal in the 5400 square miles of British coal-fields is somewhere about 35 feet.

If we direct our attention for a moment to the coal-fields of France and Belgium, we find it recorded that the *Basin of the Loire* has a total thickness of 257 feet of coal, measuring all its seams, many of which are, however, too thin for mining. One bed, the "Great Moss," contains from 26 to 39 feet; and one group of the Coal-measures, that of Rive-de-Gier, includes five workable beds, the mean aggregate amount of coal in which is 65 feet.

The *Westphalian Basin*, or that of *Ruhr*, a continuation apparently of that of Belgium, embraces in one group of strata, 1700 feet thick, as many as fifty-six beds of coal, having a united thickness of 140 feet. Of course these thicknesses much exceed the average mass of coal for the entire areas.

The relative superficial magnitudes of the coal-fields of the several countries possessing coal, will be more clearly recognised if we compare them by some simple unit of measure. Let this be 100 square miles. In this case,

Russia will be represented by	1
Spain,	2
Anthracite fields of Pennsylvania, and coal-fields of Westphalia and Bomheia, each by	4
Belgium,	5
France,	10
Rhenish Prussia,	10
British Islands,	54
British provinces of North America,	75
Europe,	90
Pennsylvania,	126
Appalachian Coal-field,	555
The United States,	2000

To approximate more correctly to the relative amounts of coal in the several great coal-fields of the world, we must compare the cubic quantities, deduced from the foregoing statements of the areas in square miles, and the respective depths of available coal,—thus calculated :

	Tons.
Belgium (assuming her coal-fields to have an average thickness of 60 feet of coal) contains about	36,000,000,000
France (with same thickness) about	59,000,000,000
The British Islands (adopting 35 feet as the average thickness) nearly	190,000,000,000
Pennsylvania (computing her average of workable coal at 25 feet) has	316,400,000,000
The Great Appalachian Coal-field (adopting the same proportion),	1,387,500,000,000
The Coal-field of Indiana, Illinois, and Western Kentucky (also with an average thickness of 25 feet),	1,277,500,000,000
The Missouri and Arkansas Basin (accepting 10 ft. as the mean thickness of the coal over the whole area),	739,000,000,000
All the Productive Coal-fields of North America (with an assumed thickness of 20 feet of coal, and a productive area of 200,000 square miles),	4,000,000,000,000

The ratio of the actual quantities of coal, in the more important of these several coal-fields, is approximately shown in the following series of numbers :—Thus, making the coal of Belgium, or 36,000,000,000 tons, our *unit of measure*,

The amount of coal in Belgium is represented by	1
In France, by less than	2
In the British Islands, by rather more than	5
In Pennsylvania, by a little less than	9
In the Appalachian coal-field, by about	38½
In the Illinois, Indiana, and Westn. Kentucky Basin, by	35½
In the Missouri and Arkansas Basin,	20½
In all the coal-fields of North America,	111
In all Europe,	8¾

COMPARATIVE QUANTITIES OF FUEL IN COAL LANDS AND FOREST LANDS.

France contains, according to M. Burat, about 280,000 hectares of Coal-measures, while its vegetable fuel is the product of 8,500,000 hectares of forests, or of a surface thirty times as great. But the vegetable fuel is four times as much as all the coal; though whether this comparison is in measure or weight is not stated. Therefore an acre of coal-field in France yields seven or eight times as much fuel as an acre of woodland.

Let us now contrast the rich coal-lands of the United States with the rich forests, acre for acre.

Good timber-lands will yield 200 cords of wood (all cut) per acre, equivalent in efficiency as fuel to 100 tons of coal; but an acre of good coal-land contains from 30,000 to 40,000 tons of coal, or three hundred or four hundred times as much fuel (estimated not by bulk or weight, but by heating power) as the best woodland.

DYNAMIC VALUE OF COAL.

It is interesting to compare the dynamic force of coal applied as fuel to the generation of steam in the steam-engine, with the dynamic effect of a man. The human labourer, exerting his strength upon a treadmill, can raise his own weight, say 150 lb., through a height of 10,000 feet per day, equivalent to 1 lb. raised 1,500,000 feet. The mechanical virtue of fuel is best estimated by ascertaining the number of pounds which a given quantity, say 1 bushel, will raise to a given height, say 1 foot, against gravity. In the steam-engine this is called the *duty of the fuel.* Now, the present maximum duty of 1 bushel of good coal, in the improved Cornish steam-engines, is equivalent to 100,000,000 lb. lifted through 1 foot; but 1 busbel has been made to raise 125,000,000 lb. 1 foot high, or 1 lb. 125,000,000 feet; but as there are 84 lb. in one bushel, this divisor gives 1 lb. as equal to 1,500,000 feet; which is just the result of a man's toil for one day upon a treadmill. Thus a pound of coal is really worth a day's wages. If we estimate a lifetime of hard work at twenty years, giving to each year three hundred working days, we have for a man's total dynamic effort six thousand days. In coal this is represented by the amazingly small amount of *three tons.* Another proof of the extraordinary power derivable through the combustion of fuel is presented in the following calculation:—1 cubic inch of water is convertible into steam of one atmosphere of pressure by 15⅓ grains of coal, and this expansion of the water into steam is capable of raising a weight of 1 ton the height of a foot. The 1 cubic inch of water becomes very nearly 1 cubic foot of steam, or 1728 cubic inches. When a vacuum is produced by the condensation of this steam, a piston of 1 square inch surface, that may have been lifted 1728 inches, or 144 feet, will fall with a velocity of a heavy body rushing by gravity through one-half of the height of the homogeneous atmosphere, or through 13,500 feet. This gives a terminal velocity of 1300 feet per second—greater than that of the transmission of sound. From this we can form some estimate of the strength of the tempest which alternately blows the piston in its cylinder, when elastic steam of high pressure is employed. Applying the calculations of the dynamic efficiency of coal for estimating the mechanical strength latent in the coal-fields of the earth, or in the large coal product annually furnished by the mines of Great Britain, we get some interesting results. Each acre of a coal-seam, 4 feet in thickness, and yielding 1 yard nett of pure fuel, is equivalent to about 5000 tons, and possesses, therefore, a reserve of mechanical strength in its fuel equal to the life-labour of more than 1600 men. Each square mile of one such single coal-bed contains 3,000,000 of tons of fuel, equivalent to 1,000,000 of men labouring through twenty years of their ripe strength. Assuming, for calculation, that 10,000,000 of tons, out of the present annual product of the British coal-mines, namely 67,000,000, are applied to the production of mechanical power, it follows that England annually summons to her aid an army of 3,500,000 fresh men, pledged to exert their fullest strength through twenty years. Her actual annual expenditure of power, then, is represented by 70,000,000 of able-bodied labourers. The latent strength resident in the whole coal-product of the kingdom may, by the same process, be calculated at more than 400,000,000 of strong men, or more than double the number of the adult males now upon the globe.

AMOUNT OF COAL MINED.

The annual product of the chief coal-fields of the world at the present time, as stated by the best authorities, would appear to be as follows:—

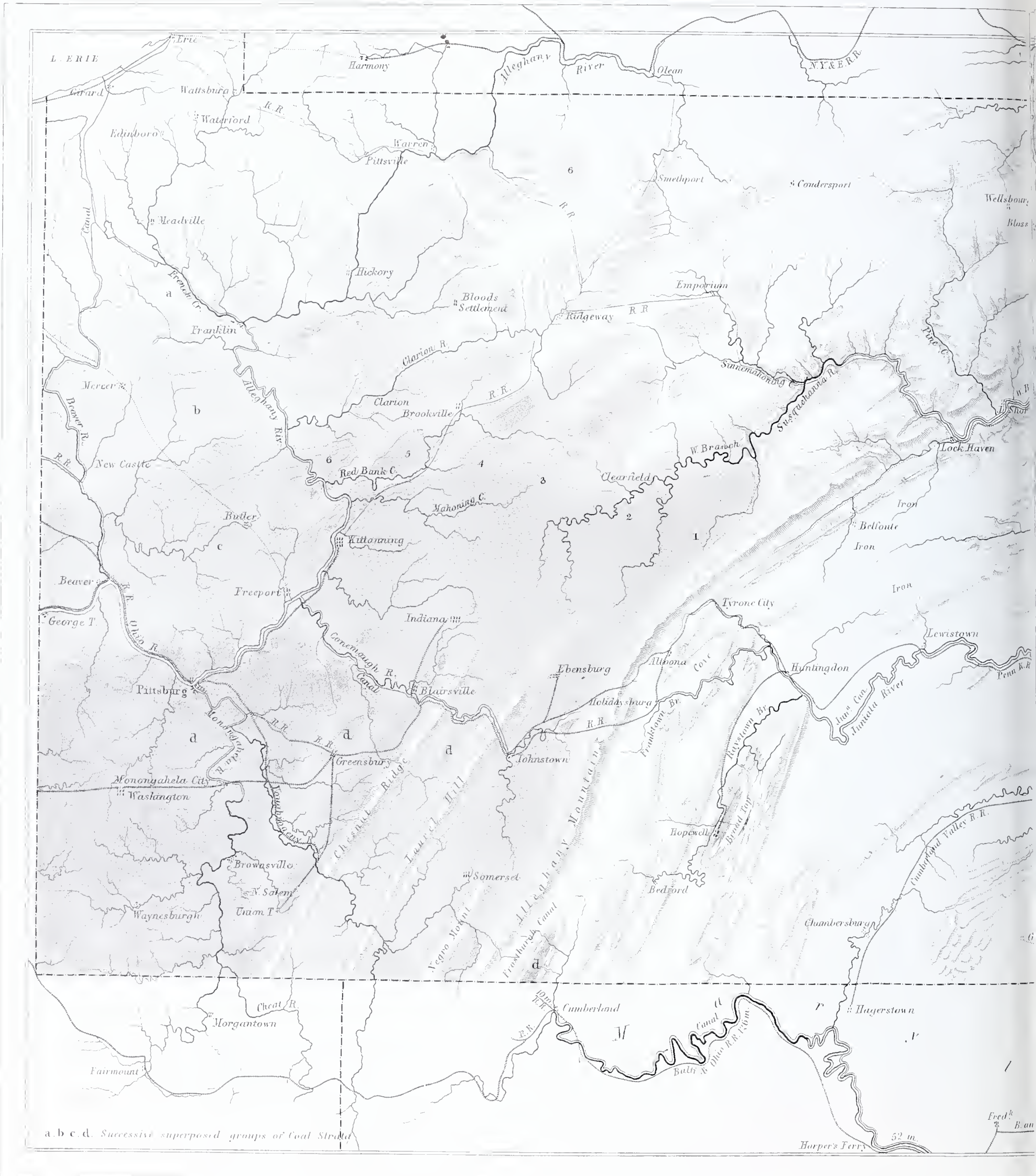
Great Britain extracted from her mines, in 1854, 64,661,401 tons, and is supposed to be producing at present about 67,000,000 tons; the United States, in 1857, about 10,500,000 tons; Belgium, in 1850, 5,820,588 tons; France, in 1850, about 4,500,000 tons; Prussian State, in 1850, 4,000,000 tons.

Thus we may fairly assume that the total quantity now annually mined very nearly amounts to 100,000,000 tons. What portion of this large production is applied to the generation of mechanical power we do not know; but it can be calculated that one-fifth of it (20,000,000 tons) is consumed annually in the manufacture of iron alone, where, however, only a part is converted into power. Probably at least 10,000,000 of tons are applied to the propulsion of machinery of all kinds, through the generation of steam.

COAL-TRADE OF PENNSYLVANIA.

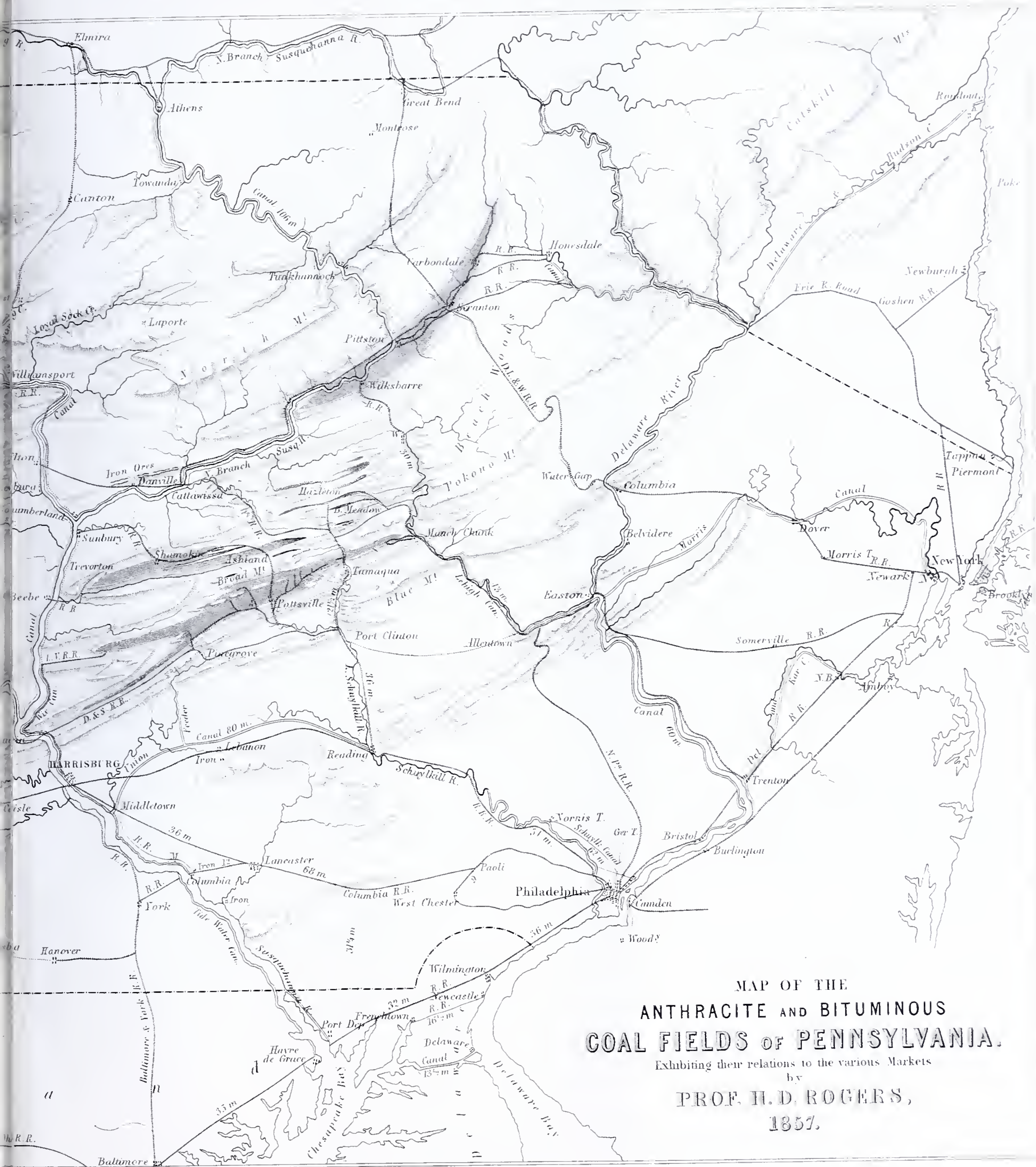
The history of the coal-trade of Pennsylvania is interesting. The produce of the anthracite mines, from its commencement in 1820 through all its stages of growth, is fully shown in the Table here affixed, which I take the liberty of copying from the *Miners' Journal* of Pottsville, an admirably-conducted paper, devoted to the coal and iron interests of the State, and abounding in valuable statistical information.

From these statistical details it would appear that, since its origin in 1820, the anthracite trade has grown in thirty-eight years to nearly 7,000,000 tons, or at the rate of about 184,000 tons per annum; and that from 1839 (the date of active development of the mines) to 1849, the product doubled itself each five years, while its subsequent rate of increase has been to double itself to its present point in eight years. The British coal-trade grows more slowly, doubling about every twenty-four years.



a.b.c.d. Successive superposed groups of Coal Strata

Entered according to Act of Congress in the Year 1857 in the Clerks Office of the District Court of Pennsylvania



MAP OF THE

ANTHRACITE AND BITUMINOUS

COAL FIELDS OF PENNSYLVANIA.

Exhibiting their relations to the various Markets

by

PROF. H. D. ROGERS,

1857.

CHARCOAL FURNACES—(*continued*).

	1854.—Tons.	1855.—Tons.	1856.—Tons.
Tennessee,	38,596	30,000	30,000
Missouri,	5,213	6,000	13,201
West Kentucky,	5,000	5,000	5,000
East Kentucky,	22,830	15,580	21,160
South Ohio (charcoal and coke),	56,081	47,182	69,605
North Ohio (charcoal and coke),	8,289	6,025	7,901
Illinois, Indiana, Michigan, Wisconsin, and Minnesota,	5,000	5,000	50,000
Total tons,	713,366	705,745	782,958

There are ten principal centres of the iron manufacture in the United States:—

1. Northern New York, once including Vermont, and using the fine primitive ores of the Adirondac Mountains. Here are forty bloomeries and three anthracite furnaces.

2. The Highlands, a narrow belt extending through Berkshire, Massachusetts, into Southern Vermont, and through Northern New Jersey into Pennsylvania, containing forty-four charcoal and twenty-two anthracite furnaces, and sixty forges, using hæmatite and magnetic ores.

3. Eastern Pennsylvania and North-eastern Maryland, with ninety-eight anthracite furnaces, one hundred and three charcoal furnaces, and one hundred and seventeen forges; none of which last, however, produce iron from the ore. This great iron region is itself divisible into distinct smaller areas, some of them using magnetic, some hæmatite, and some fossil ores.

4. North-western Virginia and South-western Pennsylvania is a distinct region on the E. outcrop of the lower Coal-measures, with forty-two charcoal furnaces, and two or three forges, and using carbonate of iron. It includes the Cambria ironworks, which accounts for its apparent growth.

5. North-western Pennsylvania and North-eastern Ohio, with sixty-six furnaces, using the ores of the N.W. outcrop of the lower Coal-measures. The charcoal furnaces of this region are all going out, and the coke and raw bituminous-coal furnaces are increasing in number, size, and efficiency. All the forging of this region is done by the rolling-mills at Pittsburg.

6. The Hanging Rock, or Ironton region, crosses the Ohio River as a belt of charcoal furnaces about 15 miles wide and 100 long; forty-five in number on the Ohio side, and seventeen on the Kentucky side. Its ores are all from the lower Coal-measures, and at its Northern end stone-coal is beginning to be used for fuel.

7. The old manufacturing region of Middle and Eastern Virginia is a prolongation Southward of the Eastern Pennsylvania, with the same ores, but using charcoal exclusively as a fuel. East of the Blue Ridge are sixteen furnaces (only one of which remains in blast), and W. of the Blue Ridge thirty. There are thirty-five forges.

8. North-eastern Tennessee and North-western North Carolina have nine furnaces and forty-one bloomery forges in a compact area. Along the base of the Cumberland Mountains, five furnaces and fourteen forges use the Dyestone fossil (upper Silurian) ore. In the S.W. corner of North Carolina are five forges, and through the middle of the State runs a belt of five furnaces and twenty-seven forges. This whole country possesses incalculable resources for iron-making, and must become at some distant day one of the great centres.

9. In Western Tennessee and Kentucky, around Clarksville and Eddyville, lies the principal, and, at present, only important region of the Far West. It contains forty-five furnaces and some forges.

10. In Missouri a beginning has been made with seven furnaces, which must develop into a great iron-making region around the Iron Mountain and Pilot Knob, when fed by coals from Western Missouri and Kansas.

The Lake Superior iron region has been opened as a mining region only within two or three years past, though it is worked with great success at various points near the copper-mines in Michigan, and on the W. shore in Minnesota. Most of the ore is shipped to Detroit and Cleveland, for the use of the rolling-mills of the West. The total production of these ores was probably 15,000 tons in 1857. This will, at no distant day, be a principal iron-making region.

Tabulating these regions on the scale of their importance, we have:—

	Tons.
1. Eastern Pennsylvania and Maryland charcoal, 87,773; anthracite, 341,928,	428,701
2. Ironton Region, South Ohio,	90,765
3. Highland Belt,	70,672
4. Pittsburg Region,	69,488
5. Clarksville and Eddyville Region,	33,000
6. Adirondac Region,	34,464
7. Monongahela Region,	30,867
8. Missouri Region,	13,201
9. East Tennessee and Carolina Region,	6,800
10. Virginia,	5,730
Total,	782,958

Bloomery forges are small open blast-furnaces, or very large smith-fires closed in to hold a quarter of a ton of some rich ore, which when smelted is hooked out in the form of a ball of malleable iron, and hammered round or flat under a tilt-hammer. All the forges are adjuncts to the blast-furnaces, treating their pig-iron in the same manner as if it were so much ore, and preparing it for the rolling-mill. It is a great geographical feature of the manufacture that the forges are to be found almost exclusively East of the Alleghany Mountains; the geological reason for which is, that here alone are found the magnetic, primary, or high per-cent ores. Lake Superior and Missouri are the only Western forge regions. The West once had many forges for blooming pig-iron, but these have all been abandoned, and that work is now done by the puddling furnaces, squeezers, and muck-roll of the rolling-mills. There is a third division of forges, which use either trip or steam hammers for turning bloomed and rolled iron into various shapes for mechanical purposes—engine cranks and shafts, car-axles, &c.

Rolling-mills (commonly with nail-factories attached) are divided into railroad and merchant mills. The principal railroad-mills in the United States are given in the following Table, with their product in 1856:—

Bay State, Boston,	17,871 tons.	Mount Savage, Maryland,	7,459 tons.
Rensselaer, Troy,	13,512 „	Cambria, Pennsylvania,	7,533 „
Trenton, New Jersey,	about 13,000 „	Brady's Bend, W. Pennsylvania,	13,206 „
Phœnix, Pennsylvania,	18,592 „	Washington, Wheeling, Virginia,	2,355 „
Pottsville, Pennsylvania,	3,021 „	McNickle, Covington, Kentucky,	1,976 „
Lackawanna, Pennsylvania,	11,338 „	Railroad Mill, Cleveland, Ohio,	1,800 „
Rough & Ready, Danville, Pa.,	5,259 „	Newburg Mill, Cleveland, Ohio,	900 „
Montour, Danville, Pennsylvania,	17,538 „	Wyandotte, near Detroit,	6,000 „
Safe Harbour, Lancaster Co., Pa.,	7,347 „		
		Total,	147,507 „

The Fairmount, at Philadelphia, has been recently adapted to rolling railroad-iron, and the Palo Alto, at Pottsville, rolled about 1000 tons in 1856. The Newburg mill commenced making rails late in 1857. Most of these mills are now stopped; and a number lately about to be erected in the West (at Indianapolis, Chicago, St Louis, &c.) will have to be delayed till better times. The Western mills chiefly re-roll old rails. The extension of this business in the past four years can be seen from the following figures:—

	Railroad Iron made. Tons.	Imported. Tons.	Consumed. Tons.
1853,	105,000	298,895	403,995
1854,	121,000	288,266	409,866
1855,	134,000	127,915	261,915
1856,	147,507	155,995	303,502

NICKEL AND COPPER MINE OF THE GAP, LANCASTER COUNTY.

Since putting to press the account of the Minerals and Ores of the State embodied in Part IV. of this work, some additional information has reached me respecting the Old Nickel and Copper Mine of Lancaster County. It has been reopened, chiefly with a view to the nickel, this metal being now in demand at the United States Mint, for the manufacture of the beautiful new nickel *cent*. The lode is reached by a vertical shaft 23 fathoms deep. A gallery, about 300 feet long, follows the ore at a depth of 10 fathoms; at one end of it the vein divides into three or four branches. A wide cross-course has been cut about 100 feet E. of the shaft, intersecting chiefly sulphate of iron and actinolite. East of this occur several irregular, thin, vanishing veins of black oxide and red sulphuret of copper; but these disappear as they approach a mass of sienitic granite. At this spot, it is said, the mine was first opened, nearly one hundred and thirty years ago, and was wrought, but unsuccessfully, for the copper ore. At a short distance below the 60-feet or 10-fathom level, the lode acquires sulphuret of nickel; and at the depth of 16 fathoms it presents a somewhat rich body of nickel ores within a width of 20 feet. At this depth the principal gangstone is hornblende; but going deeper, the hornblende diminishes, and the nickel ore augments, so that not more than 20 or 25 per cent of the material raised requires washing. Small veins and bunches of yellow sulphuret of copper, yielding about 14 per cent of metal, occupy the N. part of the lode, through a breadth of some 7 feet. Towards the W., at a depth of 21 fathoms, the lode is said to yield good nickel ore, in the proportion of 18 tons of ore to each cubic fathom of the lode: it is estimated that a miner can extract about 20 tons of nickel ore per month. This lode has been explored by trial-shafts to a depth of 10 fathoms, for a length of about 600 feet, and looks well throughout.

About 90 feet N. of the lode mined, there occurs another vein parallel with it. This has been explored through a length of more than 900 feet. At a depth of 70 feet a shaft exposes sulphuret of nickel and copper ores; it dips about 33° N. Mr Joseph Buzzo, mining engineer, from whose printed statement these details are derived, estimates the quantity of "nickel ores now discovered to be at least one hundred thousand tons," and says that "the produce of the mine at present is about 200 tons of nickel ore and 10 tons of copper ore per month. There are ten miners employed, and eighteen surface-hands, including mechanics."

ADDITIONAL ILLUSTRATIONS.

A FEW woodcuts which were overlooked, or were not prepared when the pages which they were designed to illustrate were made ready for the press, are here introduced. Copiously as the text is elucidated, I am unwilling that it should lose the assistance of even these few sketches, which, however misplaced in the printing, can readily be turned to profit by the judicious reader.

Taking them nearly in the order in which they should have appeared in the book, the first omitted cut, Fig. 774, here annexed, represents a section of the Nittany or Bellefont Valley, near Jacksonville. Its appropriate place is page 497 of Vol. I., where the dislocated axis of the Nittany Valley is represented as an "upthrow on the South," lifting the Primal rocks upon the edges of the inverted Auroral limestone along the margin of the "Barrens." It exemplifies, moreover, the general description given at page 897, Vol. II., of a dislocation at an anticlinal axis-plane, where, in a folded flexure, the uninverted side of the wave is shoved upward and forward upon the inverted side.

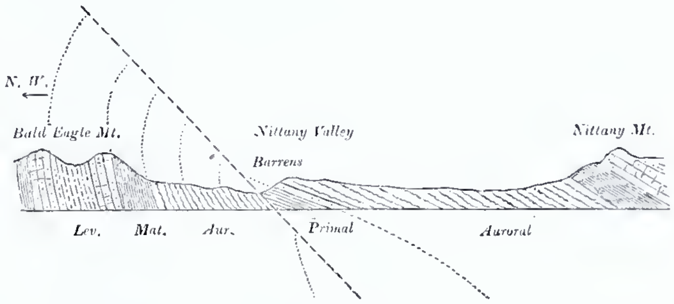


FIG. 774.

Another section, too illustrative to be overlooked, is here appended in Fig. 775. It is intended to explain the structure of a part of the interesting undulated country embraced between Jack's Mountain and Bald Eagle Mountain, comprising Kishacoquillas and Penn's valleys, and the ridges protruding into them. It should have appeared at page 462, Vol. I. It illustrates well some of the prevailing laws of the Appalachian flexures, and should be consulted by the reader when perusing the Essay on the "Laws of Structure of Disturbed Zones," beginning at page 885, Vol. II. It exemplifies, too, the erosion of synclinal ridges, discussed on page 924 *et seq.*, of Vol. II.

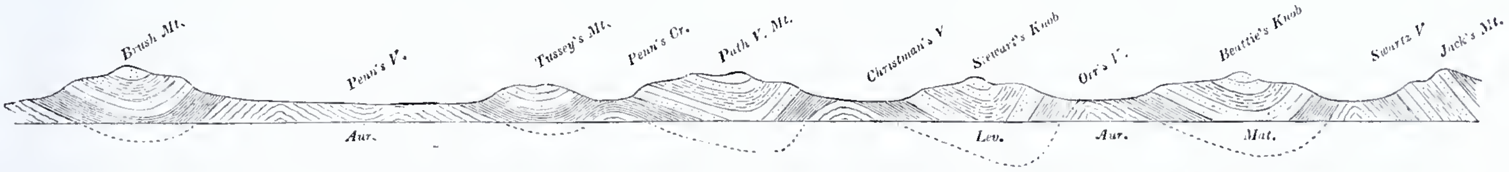
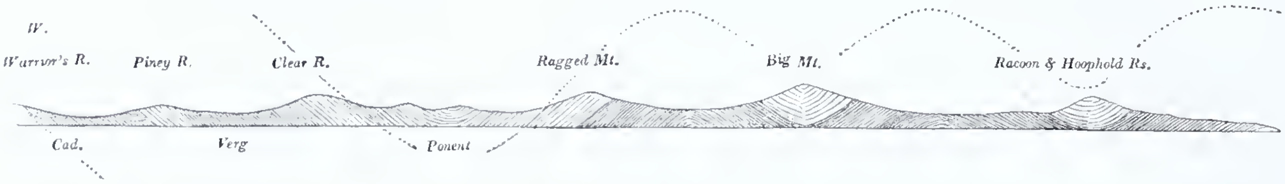


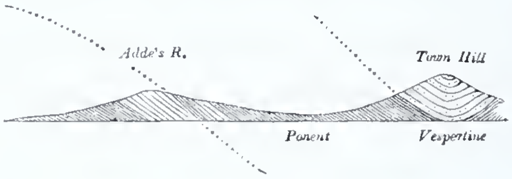
FIG. 775.—Section through Penn's Valley and East end of Kishacoquillas Valley, showing Terraced Ridges.

The section here introduced (Fig. 776) illustrates the structure of the E. part of Bedford County, between the terminal knob of Town Hill and Warrior Ridge (see Vol. I., pp. 523, 527).

Fig. 776.—Section from Gap in Town Hill to Warrior Ridge, along the Rainsburg Road.—1 *inch* = 1 *mile.*



It displays three parallel nearly equidistant flexures in the Vergent strata, and exemplifies beautifully the influence of denudation in producing valleys at the summits of the waves and ridges at their troughs.



This section (Fig. 777), representing the country between Jack's Mountain and Tussey Mountain, immediately S. of the Frankstown branch of the Juniata, will assist in elucidating parts of the chapter on Stone Valley (Vol. I., p. 512). It intersects the end of Terrace Mountain, and displays well the structure of Jack's Mountain at the river.

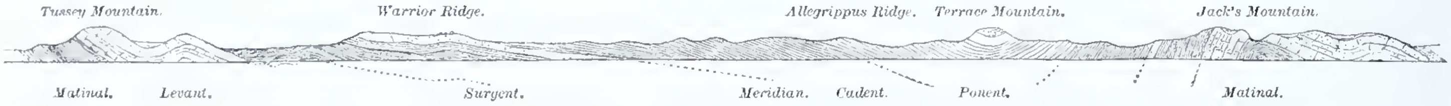


Fig. 777.—Section from Tussey Mountain, near Alexandria, to Jack's Narrows of the Juniata, 17 miles.

The annexed interesting topographical section (Fig. 778), from the Southern Anthracite basin near Tamaqua to Buck Mountain, illustrates the general structure of the Eastern Middle Anthracite coal-field, and should have appeared on page 239 of Vol. I. It displays clearly the six synclinal belts into which this coal-field is subdivided by its five great anticlinal flexures, and the plateau form of the basins. The beholder is supposed to be looking N.E. from a point above the Broad Mountain.

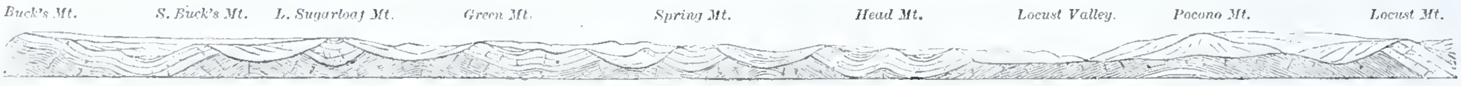


Fig. 778.—Section from the neighbourhood of Tamaqua, across Locust Valley and the West ends of the Beaver Meadow and Bucks Mountain Basins.

Note.—*The allusion at page* 75 *of this Volume to the earnings of the Lehigh Coal and Navigation Company is not correct. The Report of the Managers for* 1856 *shows that in that year the earnings exceeded the expenses by rather more than* $445,000. *The paragraph crept into print through an oversight, such topics being irrelevant to the purposes of this work.*—H. D. R.

GLOSSARY.

Acephalous (Gr. *a*, without, and *cephale*, a head).—Applied to the molluscous animals, like the oyster, which have no distinct head. Most of the bivalve shells are embraced in the class Acephala.

Adit.—A horizontal tunnel penetrating from the surface into a mine, and designed as an outlet for water.

Algæ (Lat. *alga*, sea-weed).—An order of cellular aquatic plants, embracing the sea-weeds and many fresh-water species.

Alluvium (Lat. *ad*, together, and *luere*, to wash).—A deposit of materials washed together by rivers, floods, and other moving waters, upon lands not permanently submerged.

Anticlinal (Gr. *anti*, on opposite sides, and *clino*, I bend).—A term expressive of the dipping or declining from each other of two sets of strata, or two portions of one stratum, as the two slopes of a wave do.

Arenaceous (Lat. *arena*, sand).—Sandy.

Argillaceous (Lat. *argilla*, clay).—Clayey.

Auroral (Lat. *aurora*, the time just before sunrising). — The second series of the North-American Palæozoic strata. The term has been chosen to express the early morning or daybreak period of the Appalachian Palæozoic day. The Auroral limestones are called, in the New York nomenclature, the Black River and Chazy limestone and calciferous sandstone. They represent nearly the middle Cambrian or Festiniog group of Professor Sedgwick.—(See vol. ii. p. 752, and vol. v. p. 105.)

Axis (Lat. *axis*, a pole or axle-tree).—Signifies in geology the line of sharpest bending, whether convex or concave, of a stratum. The Anticlinal Axis is equivalent to the crest of a convex wave; the Synclinal Axis to the line of greatest depth in a trough or concave wave.

Azoic (Gr. *a*, without, *zoè*, life).—Applied to a group of rocks underlying the Palæozoic, and destitute of all traces of once vital organisms.

Basalt.—A common variety of the trappean rocks; usually dark green or nearly black; hard, close-grained, and sometimes regularly columnar. It is an igneous rock, composed of augite and felspar.

Basin.—A concave or trough-like form in a set of strata; sometimes applied to very wide areas, in which the strata are centrally horizontal, and rise to the surface only at the margin.

Benches.—Steps or terraces on the slope of a hill, sometimes used by miners to signify the layer in a compound seam of coal.

Bitumen (Gr. *pitus*, mineral pitch or tar).—An inflammable substance, which burns with much smoke and flame like pitch. The inflammable materials of the so-called bituminous coals are not true bitumens, but various other compounds of hydrogen and carbon.

Blackband.—A miner's term for a coaly variety of ironstone, or clay iron-ore, which contains fuel enough to calcine the ore without additional coal.

Bloom.—A large lump of malleable iron, before it is rolled or hammered into shape.

Bloo'mery.—A small furnace for the production of malleable iron by direct contact with charcoal or coke.

Boulders.—Large partially-rounded lumps of rock imbedded in gravel and clay, and supposed to have been rolled by water or transported by ice.

Brachiopoda (Gr. *brachys*, an arm, and *pous*, *podos*, a foot).—An order of mollusca provided with spiral arm-like organs, and for the most part enclosed in two valves or shells.

Breaker.—A mill-like structure, supplied with machinery for breaking, freeing from slate, and sorting anthracite coal at the mines.

Breast.—A miner's term to express the portion of a sloping bed of coal or other stratum, included between one horizontal gallery and another above it, or between such a gallery and the outcrop.

Breccia (Ital., a crumb or fragment).—Any rock composed of recemented angular fragments.

Bryozoa (Gr. *bryos*, moss, and *zoon*, an animal).—Minute molluscous animals congregated upon a common stock, very much as the compound polypes are, each animal residing in a separate cell. The living *sea-mats*, Flustræ, are examples of this class.

Buhr-stone.—A porous silicious rock, used for mill-stones.

Cadent (Lat. *cadens*, falling, waning).—A series or group of the Appalachian strata, metaphorically expressive of the declining of the American Palæozoic day. It is equivalent to a part of the older Devonian series of Europe.—(See vol. i. p. 107, and vol. ii. p. 755.)

Cainozoic (Gr. *kainos*, recent, and *zoè*, life).—Applied to the upper or Tertiary strata imbedding remains of recent or living forms of life.

Calamite (Lat. *calamus*, a reed).—A reed-like jointed stem, resembling the living equisetum, and found in the coal strata.

Calcareous (Lat. *calx*, *calcis*, lime).—A rock containing a sensible proportion of lime; usually in the form of the carbonate of lime; is said to be calcareous.

Cambrian.—A term applied to the oldest great series of strata embraced in the Palæozoic system of rocks. The word is derived from the classic name of *Wales*, where these deposits are largely developed.

Carboniferous (Lat. *carbo*, coal, and *fero*, I yield).—Coal-yielding or coal-bearing. Applied to the series of strata embracing the great coal-formation.

Cephalopoda (Gr. *kephalè*, head, and *pous*, *podos*, a foot).—The most highly organised class of mollusca, furnished with foot-like organs around the head. It includes the nautilus, cuttle-fish, &c.

Chert.—A rock consisting almost exclusively of silica. Buhr-stone is a porous variety of chert.

Chlorite (Gr. *chloros*, greenish).—A mineral, often in thin scales, resembling mica, and generally of a dark-green colour. It is a constituent of chlorite schist, one of the metamorphic rocks.

Cleavage.—A tendency in rocks to split in thin plates in a uniform direction, which is irrespective of lamination or original bedding.

Conformable.—Strata lying in parallel order one above another.

Crinoidea (Gr. *krinon*, lily, and *eidos*, form).—Lily-shaped. A class of fossil echinoderms supported on slender-jointed stems, and somewhat resembling a lily in outline.

Crop.—The edge of any inclined bed or stratum as it is exposed at the surface.

Cycadites.—Fossil plants allied to the living genera Cycas and Zamia.

Cypris.—A family of minute crustacean animals having two flat valves like the bivalve shells of many mollusca.

Denudation (Lat. *de*, down, and *nudus*, naked).—The cutting away of upper strata, and the laying bare or naked of underlying ones.

Devonian.—A series of rocks intermediate in age between the Silurian and the Carboniferous. Named from Devonshire, where they were first recognised as an independent group.

Diluvium, Diluvial (Lat. *dis*, asunder, and *luere*, to wash).—Fragmentary rocky matter, which has been violently strewn by water.

Dip.—The downward inclination or angle of downward slope of strata.

Dolomite (named after M. Dolomieu).—Crystalline magnesian limestone.

Dyke (an old Saxon word for a wall or fence).—A wall-like vein or intrusion of any igneous rock filling a fissure in another formation.

Echinodermata (Gr. *echinos*, urchin, and *derma*, a skin.)—A class of radiated animals covered with a firm crustaceous integument. It embraces the star-fishes and sea-urchins.

Encrinites (Gr. *krinon*, a lily).—A fossil radiate animal, having a lily-shaped body attached to a long jointed stalk. Encrinal limestone or marble is a limestone largely composed of the joints and fragments of these fossils.

Entomostraca (Gr. *entomon*, insect, and *ostracon*, shell).—Shelled insects, crustacean animals, so named in contradistinction to the mallocostraca, or soft-bodied.

Eocene (Gr. *ēos*, dawn, and *kainos*, recent).—A term proposed by Sir Charles Lyell, and now generally used for the earliest-formed group of the Tertiary strata, from its showing the dawn of the recent or living types of life. Among its fossils, from three to six per cent belong to shell-fish now living.

Escarpment (Fr. *escarper*, to cut steep).—The steep slope or abrupt face of a hill.

Facies (Lat.)—A term of recent introduction, expressing a prevailing likeness or general aspect among organic remains, &c.

Fault.—Any dislocation in strata or a fissure accompanied by displacement.

Felspathic.—Composed of felspar; a mineral consisting of silica, combined with alumina and soda or potash, all in definite proportions.

Ferruginous (Lat. *ferrum*, iron).—Impregnated with oxide of iron.

Fireclay.—A clay destitute of alkaline earth, or other ingredients tending to melt it in a hot fire, and therefore adapted to resist intense heat.

Foliation.—The crystalline lamination of metamorphic strata.

Formation.—A stratum, or group of strata, insulated from others by its distinctive organic remains, definite composition, and stratigraphical position; it should be restricted to signify the product of one formative period or formative process.

Fossil (Lat. *fossus*, dug up).—Any relic of plant or animal imbedded in the earth's strata. It embraces not only buried organisms which have been petrified, but casts, moulds, and imprints of all such.

Fucoid (*fucus*, sea-weed, and *eidos*, form).—Fucus-like impressions met with abundantly in the older strata.

Gangway.—A level or nearly level alley, used as a roadway in a mine. Those horizontal alleys not used as thoroughfares are simply called levels.

Gap.—A term used in Pennsylvania for any deep sharp notch in a mountain-ridge. Water-gaps are those notches or passes which penetrate to the bases of the mountains, and give passage to the larger streams.

Gasteropoda (Gr. *gaster*, belly, and *pous*, foot).—Molluscous animals, which, like the snail, possess a distinct head, and move by a muscular foot attached to the lower part of the body.

Geology (Gr. *gè;* the earth, and *logos*, doctrine).—The science of the composition, structure, history, and forces discernible in our earth.

Gneiss.—A stratified, granitoid rock, composed of crystalline minerals, but displaying a regular bedding or stratification.

Gossan.—Any loose surface vein-stone containing traces of the characteristic ores of a mineral lode; usually hydrated peroxide of iron derived from the sulphuret of iron.

Granite.—A crystalline rock, the typical form of which is a triple aggregate of felspar, quartz, and mica.

Greenstone.—An ancient igneous rock, composed of felspar and hornblende.

Gypsum.—Plaster-of-Paris, or sulphate of lime in a crystalline form.

Hæmatite (Gr. *haima*, blood).—Red oxide of iron. Loosely applied in the United States to the hydrated brown oxide of iron.

Hornblende.—A dark-green or almost black mineral, heavier than quartz or felspar, but not so hard, and recognised by its peculiar bitter odour when breathed upon. It is a constituent of the granitic and trappean rocks.

Hydrogenous.—Containing hydrogen.

Hypozoic (Gr. *hypo*, under, and *zoè*, life).—A term for the gneissic and other rocks which lie beneath the fossiliferous strata. The term is conveniently restricted to the more ancient metamorphic rocks which underlie the Azoic or semi-metamorphic strata, which are also destitute of fossils, but which in many countries immediately support the Palæozoic, or those containing organic remains.

Igneous (Lat. *ignis*, fire).—A term applied to those rocks which have obviously been in a melted state from intense heat.

Jurassic.—The name of a group of secondary strata largely developed in the Jura Mountains, of later formation than the Triassic, and of earlier origin than the Cretaceous or Chalk deposits. It is synonymous with the Oolitic system of England.

Lacustrine (Lat. *lacus*, a lake).—Belonging to a lake.

Laminated.—Dividing into thin layers or leaves.

Lepidodendron (Gr. *lepis*, a scale, and *dendron*, a tree).—Fossil plants so named from the scale-like appearance of their leaf-scars.

Levant (Lat. *levare*, to lift; Fr. *lever*, to rise).—Rising: a term applied to the fourth series of the Appalachian Palæozoic strata, called in New York the Medina group, and of equivalent age to the May Hill Sandstone of England. It signifies metaphorically the sunrise period of the Palæozoic day.—(See vol. i. p. 105, and vol. ii. p. 753.)

Lignite (Lat. *lignum*, wood).—Wood-coal, or fossil wood, somewhat resembling coal.

Littoral (Lat. *littus*, the shore).—Of shore origin, in contradistinction to production in deep water.

Marl.—A limy or calcareous clay or shale.

Matinal (Lat. *matutinus*, morning).—The title employed in this work for the third series of the Appalachian Palæozoic strata, and intended to express the morning period of the Palæozoic day. The New York titles of the Matinal strata are Trenton Limestone and Hudson River Slate Group; the nearest British equivalents are the Llandilo and Bala rocks of the Cambrian series.—(See vol. i. p. 105, and vol. ii. p. 752.)

Meridian (Lat. *meridies*, mid-day).—Noonday; in allusion to the mid-day date of the strata to which it is applied. A term appropriated to certain middle formations of the Appalachian Palæozoic system, which are called in the New York Survey the Oriskany Sandstone, and which appear to be on the horizon of the lower Ludlow rocks of England.—(See vol. i. p. 107, and vol. ii. p. 755.)

Mesozoic (Gr. *mesos*, middle, *zoè*, life).—A great division of the fossiliferous strata, characterised by the middle forms of life.—(See vol. ii. p. 759.)

Metamorphism.—The transformation of strata by heat or chemical action. Metamorphic strata are sedimentary deposits which have been hardened and made crystalline without losing their laminated structure. Gneiss and mica-schist are examples.

Miocene (Gr. *meion*, less, *kainos*, recent).—A name proposed by Sir Charles Lyell for the middle Tertiary strata, on the ground of their containing a less proportion of recent (usually from 18 to 24 per cent) than of extinct shells.

Mollusca.—Literally, soft animals; a division of the Invertebrata devoid of bones, but for the most part encased in shells.

New Red Sandstone.—The lowest Mesozoic group, or Trias.

Old Red Sandstone.—A formation of the Devonian series, named from its lying below the Coal-formation, in contradistinction to the New Red, which overlies it.

Oolite (Gr. *oon*, egg, *lithos*, stone).—Limestone, consisting chiefly of small, spherical granules, like the egg or roe of a fish. The Oolitic structure may occur in limestones of all ages, but abounding chiefly in those of the Middle Mesozoic period, all the formations of that epoch are called Oolitic. The synonym Jurassic is getting to be more used.

Orthocerata (Gr. *orthos*, straight, *xeras*, horn).—A family of the cephalopodous class of molluscs. They are straight, horn-like shells.

Palæontology (Gr. *palaios*, ancient, *onta*, beings, *logos*, doctrine).—The science of ancient or extinct animal and vegetable fossil remains.

Palæozoic (Gr. *palaios*, ancient, *zoè*, life).—The most ancient or lowest great division of the fossiliferous strata.

Pleistocene (Gr. *pleistos*, most, *kainos*, recent).—A term applied to those strata next older than those now in process of formation; the word imports that the organic remains belong almost wholly to species now in existence. Some geologists use it as synonymous with Post-tertiary or Quarternary; others, with more propriety, make it a division of the Cainozoic period.

Pliocene (Gr. *pleion*, more, *kainos*, recent).—A term proposed by Sir C. Lyell, and now much used, for an upper Tertiary group of strata, implying that they contain more of recent than extinct organic remains.

Polyzoa or Bryozoa.—A class of mollusca embracing animals enclosed in cells organically associated, having a receiving and discharging orifice placed near together, and a mouth surrounded by ciliated tentacles.

Ponent (Lat. *ponere*, to set).—Setting: the name of the twelfth series of the Appalachian strata, nearly equivalent in age to the Old Red Sandstone of Great Britain. It expresses metaphorically the sunset period of the Appalachian Palæozoic day.—(See vol. i. p. 108, and vol. ii. p. 756.)

Porphyry (Gr. *porphyreos*, purple).—Any igneous rock, of whatever colour, composed of a pasty mass imbedding distinct crystals.

Post-meridian (Lat. *post*, after, *meridies*, noon).—Afternoon: a term applied to the series of the Appalachian strata, which in the New York Survey has been called the Upper Helderberg or Corniferous limestone. The word refers to the part of the Appalachian day at which the group was formed.—(See vol. i. p. 107, and vol. ii. p. 755.)

Pre-meridian (Lat. *præ*, before, *meridies*, noon).—Forenoon: one of the Appalachian Palæozoic series of strata, named from the relative date of its origin. It is a synonym for the Lower Helderberg limestones of New York.—(See vol. i. p. 107, and vol. ii. p. 754.)

Primal (Lat. *primus*; O. E. *prime*, the earliest dawn).—The earliest Palæozoic series of the Appalachian Basin, named from originating in the dawn of the great Palæozoic day of North America.—(See vol. i. p. 104, and vol. ii. p. 751.)

Primary, Primitive.—Formerly applied to all the most ancient crystalline non-fossiliferous rocks, but fast becoming obsolete. The term Primary fossiliferous strata is sometimes used as synonymous with Palæozoic.

Pyrites (Gr. *pyr*, fire, *ites* for *lithos*, stone). —The name given to the combinations of iron, copper, and certain other metals, with sulphur.

Quaquaversal.—Dipping in all directions from a common centre.

Scalent (*scala*, a ladder).—Climbing: applied in the nomenclature of the Appalachian strata to a series of rocks, equivalents of the Onandaga salt and water-lime groups of New York, produced in the high morning period of the American Palæozoic day. —(See vol. i. p. 106, and vol. ii. p. 754.)

Schist (Gr. *schisma*, division).—Applied to rocks of a foliated structure which split in thin irregular plates, and not by parallel cleavage.

Schorl.—Black tourmaline.

Schute.—An inclined trough for the conveyance of mineral matter from one elevation to a lower; employed at landings for discharging coal into boats and railroad cars. The name is also applied to narrow sloping galleries within the coal-mines, down which the coal is pushed to the gangways.

Seam.—Strictly a line or plane of separation, but applied in geology to thin regular layers or subordinate strata, especially to beds of coal, for which it is a preferable term to the word vein, in common use in Pennsylvania.

Secondary Strata.—Applied originally to all fossiliferous strata above the Primary or non-fossiliferous, and below the Tertiary. If used at all, it should be restricted to signify Mesozoic.

Section (Lat. *sectus*, cut through). —An actual or ideal exposure of any part of the earth's crust, showing the strata edgewise, as if they were laid open by a cut.

Seral (Lat. *sero*, late; Fr. *soir*, night).—Late: a synonym for the coal-formation, expressing the period of the nightfall or late twilight of the Appalachian Palæozoic day.—(See vol. i. p. 109, and vol. ii. p. 758.)

Series.—A natural group of formations distinguished from all others by characteristic organic remains. Less comprehensive than the word system, which is reserved for the greater divisions—the Palæozoic, &c.

Shale (Ger. *schalen*, to peel or shell off).—Applied to the clay-derived or argillaceous rocks which split or peel off in thin laminæ or scales. It differs from slate in signifying an irregular splintery cleavage—slate expressing a more regular leaf-like lamination.

Silicious (Lat. *silex*, flint). — Applied to rocks containing silex or quartz.

Slate.—A term restricted to those argillaceous rocks which possess a regular cleavage, or nearly parallel lamination.

Slope.—In coal-mining, means a slanting pit or shaft, descending in the plane of a coal-bed, and provided with a double railway-track, stationary steam-power, and pumping apparatus for winding up the coal and pumping the water from the mine.

Splint or Splent Coal.—A Scotch name for a firm variety of bituminous coal which breaks in elongated slabs.

Stratum—plural, Strata (Lat. *stratum*, strewn or spread out).—Any layer or group of layers of sedimentary matter. Unstratified rocks are such as exhibit no indications of having been formed in layers.

Strike.—The direction or trend of any rock traced horizontally.

Sump.—A miner's term for a shallow pit or well at the bottom of a mine-shaft or slope, into which the water of the mine is made to drain, and from which it is lifted by pumping to the surface.

Surgent (Lat. *surgere*, to rise).—Rising: the fifth series of the Appalachian strata, synonymous with the Clinton group of New York, and partially equivalent in age to the Silurian Wenlock formation of England. The term has a metaphorical allusion to the period succeeding the sunrise, or that of the ascending day.—(See vol. i. p. 106, and vol. ii. p. 753.)

Synclinal (Gr. *syn*, together, and *clino*, I bend).—A term significant of a trough-like structure, or the dipping towards each other of two sets of strata.

Tertiary.—The third or upper great division of the stratified rocks. Still much in use, though the synonymous term Cainozoic is preferable.

Trap, or Trappean (Swed. *trappa*, a stair). —A name applied to certain igneous or volcanic rocks, such as tabular greenstone and basalt, which tend to assume a stair-like outline. It includes all igneous rocks, not granitic on the one hand, nor strictly volcanic on the other.

Umbral (Lat. *umbra*, a shade—dusk).—Shady: the name applied, in the nomenclature employed in this work, to the fourteenth series of the Appalachian strata, or that which corresponds in period with the carboniferous limestone of Europe; it expresses, metaphorically, the twilight or dusk of the Appalachian Palæozoic day.—(See vol. i. pp. 108, and vol. ii. p. 757.)

Vein (Lat. *vena*).—Mineral or metallic matter, filling a rent or fissure in any rocky mass. The term is not applicable to a sedimentary bed or stratum, however thin.

Vergent (Lat. *vergere*, to decline, to sink).—Declining: a series of the Appalachian Palæozoic strata equivalent to the Chemung group of New York, and of the age of the middle Devonian rocks of Europe. The term expresses, metaphorically, the descending day or period before sunset.—(See vol. i. p. 108, and vol. ii. p. 756.)

Vesicular (Lat. *vesicula*, a little bladder). —Applicable to rocks containing minute bladder-like cavities.

Vespertine (Lat. *vespertinus*).—Evening: the thirteenth series of the Appalachian strata, equivalent to the lowest carboniferous group of Europe. The word expresses the evening of the American Palæozoic day.

Volcanic (Lat. *vulcanus*).—Igneous action at the surface of the earth, in contradistinction to plutonic or igneous action deep in the interior. The phrase is generally employed for all igneous products not granitic or trappean.

Winze.—A schute, or sloping passage extending from one level to another in a lead or copper mine.

Zoophytes or Zoophyta.—Polypes; animals of a radiate structure, a gelatinous or fleshy substance provided with a crown of tentacles around the entrance to the stomach. The class embraces corals, actiniæ, &c.

INDEX.

Abel and Flexer's limest. quarries, i. 235.
Abington, Aur. limest. belt, i. 211—limest. quarries, details, i. 213.
Acadian geology cited, ii. 943.
Ackland's grist-mill, gneissic rocks, i. 84.
Acop's quarry, i. 153.
Adamsburg limest. knobs, i. 406.
Adams County, anti. belt of Pri. slates, i. 184—Aur. limest., i. 223—Mesozoic red sandst., i. 203, 207—Pri. slates, i. 123—Pri. strata, ii. 123.
Adam Stahl Vein, syn. axis to the S., ii. 32, 89.
Adam's Tunnel, ii. 203—slope coal, ii. 204.
Adder's Ridge, Cad. and Verg. rocks, dip, i. 528.
Additional sections, ii. 1023.
Ælurodon ferox, ii. 773.
Age of red sandst., ii. 693—Wheatley lode and trap-dykes, ii. 702.
Agnostus lobatus, ii. 820.
Agriochœrus, ii. 771.
Air-hole Coal, Bear Gap, ii. 192.
Albert Mine, Hillsborough, ii. 946.
Albion Mines, ii. 949.
Alethopteris, ii. 864, 865.
Alexander's Cave, dip of magnesian limest., i. 476—streams of, i. 476.
Alexander and Diarmid's ore-openings, i. 516.
Algæ, ii. 848.
Alleghany arsenal, winds at, i. 57—escarpment, i. 559—Pon. strata, i. 548—section furnace, ii. 594—Mountain, i. 19, 116, 117, 118, 119, 120, ii. 467, 480, 494, 529—Cad. and Verg. rocks, i. 540—form of the escarpment, i. 565—Seral conglomerate, ii. 24—Pon. red sandst. and shales, thickness, i. 541—Pon. rocks, thickness, i. 300—Pon. strata, i. 42—Pon. rocks, i. 440—Verg. rocks, i. 140, 141—Vesp. rocks, i. 143, ii. 143.
Alleghany River, ii. 488—its basin, i. 42—scenery and structure of, i. 36—drainage of, i. 35—origin, range, details, i. 51, 52—rise and dimensions, i. 578—tabulated details of, i. 46—section of, ii. 578—slope, limest. quarry, grindstones, i. 552—summit, ii. 652—table-land scenery, i. 34.
Allegrippus Ridge, Cad., Verg., and Pon. rocks, i. 526—Pon. rocks, i. 521.
Allentown Bridge, Pri. sandst., i. 196—to Cooperstown, structure of South Mountains, i. 100—iron ore, i. 263—east of, i. 93.
Allenville, fragments of Mat. sandst., i. 480.
Alps, the, ii. 901—generalised section of, ii. 902,
Alsboch's Coal, ii. 571.
Alterations produced by trap-dykes, ii. 685.
Alum bank, Cad. rocks, i. 563.
Amberson's Knob, i. 315, 332—Valley, i. 114, 333—13th anti. axis in the Mat. slates, i. 316—Mat. slate, i. 323—7th and 8th anti. axes in Mat. slates, i. 315—position and dimensions, i. 318.
Ambonychia bellastriata, ii. 819.
American equivalents of European strata, ii. 741, 742.
American and European coal-fields, ii. 1015.
Amount of coal mined, ii. 1018.
Amphicyon, ii. 771.
Analyses of Cad. and Verg. ores, ii. 733—of hæmatitic ores of Aur. limest., ii. 727, 728—of iron ores, ii. 740—of iron ores of coal-measures, ii. 739—ores of the gneiss, ii. 717—of Prem. ores, ii. 732—of the Pri. slates, ii. 721—of Surg. iron ores, ii. 731—of Umb. iron ores, ii. 734.
Anchitherium, ii. 771.
Anderson's Creek, ii. 484, 536—Farm, coals, ii. 337—Knob, synclinal, ii. 460.
Andersontown, i. 340—limest. ridge, i. 347—Mer. sandst. ridge, i. 352—6th anti. axis in the Verg. shales, i. 315—Surg. rock, i. 339.
Annual product of coal, ii. 1018.
Annularia, ii. 852.
Anthracite, ii. 991—coal-basins, views from their terminal knobs, i. 23—Pottsville, Plate II., ii. 152—Salem Hollow, ii. 152—coal-fields, ii. 1, 465—coal-measures, ii. 5—older coal-measures, strata thickness, ii. 17—region, structure, position, details, i. 117, 118—coal-trade, ii. 1019—conglomerate, gradation in thickness, ii. 24—districts, survey of the belts, i. 119—general limits, ii. 4—mines of the first coal-basin, i. 7.
Anticlinals, ii. 29, 364, 365—in Aur. limest. in Kittatinny Valley, i. 244.
Anticlinal axes B and E at Tamaqua, ii. 80—of bituminous coal-field, ii. 479—of Blacklog Valley and McConnellsburg Cove, i. 428—along the Blue Ridge, i. 413—N.E. of Buckstown, i. 559—at Bushy Creek, ii. 111, 112—Cad. and Verg. rocks, i. 361—between Coal Run and Buck Run, ii. 295—Eastern Mine Hill, ii. 199—in Kishacoquillas Creek, details, i. 407—in Lewistown Valley, i. 396, 403—limest. strata, i. 459—local details, i. 309—Loop Mountain, i. 482—Mer. sandst., i. 420, 422—Mine Hill, ii. 201—south of Mine Hill, origin, range, details, ii. 106—in Path Valley, i. 318—Sca. and Prem. limest., i. 418—near Scranton, details, ii. 342—around Scranton, ii. 344—Sharp Mountain, ii. 27—Sherman's Valley, i. 314—Silver Creek, ii. 119—between Silver Creek and Mill Creek, ii. 122—spurs of Bear Meadow Mountain, i. 513—Surg. and Sca. strata, i. 337, 338—third belt of Sixth District, i. 462—Western division of Fourth District, details, i. 307, 308—axis, i. 159—B, range, identity, ii. 98—of Bear Ridge, ii. 270—Buck Mountain Co.'s estate, ii. 252—Buck Ridge and Peaked Mountain, structure, ii. 210—B, north of Tamaqua, ii. 97—south of Carbon Run, ii. 289—Chiques Ridge, i. 94—Coal Run to Furnace Run, ii. 295—opposite Coal-Run Gap, origin, &c., ii. 294—west of Coal Run, details, ii. 295—C, origin, &c., ii. 96—Cove Mountain, i. 322—C, near Tuscarora, details, ii. 105—D, details, ii. 122—D, origin, range, details, ii. 85—E, ii. 122—Deep Valley, ii. 225—east of Heckscherville, ii. 202—E, origin, range, ii. 87—F, details, ii. 122—near Friedensville, i. 101—F, west, ii. 141—G, details, ii. 122—G, origin, &c., ii. 90—H, details, ii. 122—H, origin, range, details, ii 91—J, ii. 137—west of Llewellyn, ii. 46—Little Mine Run, ii. 276—west of Mill Creek basin, ii. 226—Muddy Branch, ii. 46—N, ii. 157—Nittany, Nippenose, and Mosquito Valley, i. 488—O, ii. 158, 159—P, ii. 160—Planes dislocated, ii. 897—Prater's Ridge, i. 422—Q, details, ii. 163—Roxbury, i. 261—Shade Mountain, i. 367—Shamokin, details, ii. 295—in the west bank of Shamokin Creek, ii. 289—the Swatara Railroad, ii. 40—Tuscarora Mountain, i. 331—belts of the eastern middle coal-field, ii. 239—No. 1 of coal-fields, ii. 239—No. 2 of, ii. 240—No. 3, range, ii. 241—Nos. 4, 5, ii. 242—fifth district of Palæozoic region, i. 114, 115—Pri. rocks, i. 162, 163—Barren Hill, i. 161—south of Creitz Creek, i. 184—Big Mine Run, ii. 275—comparison between southern and northern, i. 308—crests, i. 25—D, Casca William Creek, ii. 108—fingers of gneiss, i. 76, 77—flexures, ii. 2—Blacklog Valley, i. 370—Carbon Run, ii. 307—in the coal-measures, ii. 27—Coal Run Basin, ii. 297—description, ii. 3—Dry Valley, i. 409—fifth district, Palæozoic region, i. 114, 115—McCall's Ferry, i. 187—Middleton's, i. 161—Mill Creek, ii. 141—Montour's Ridge to the Alleghany Mountains, i. 453—Mount Carmel Basin, i. 270, 271, ii. 280, 281—Orwigsburg and Stroudsburg Valley, i. 113—saddles, classification, description, ii. 28—Shamokin Gap, ii. 296—sxith district, i. 116, 117—South Mountains, i. 94—Tamaqua and Port Clinton, details, i. 289—White Stone Valley, i, 512, 513—western middle coal-field, ii. 266—F, origin, &c., ii. 88, 89—F, Woodside, ii. 169—1, ii. 95—Lock and Canoe mountains, i. 554—Mine Ridge, ii. 277—mountains, examples of scenery, i. 20, 21—spurs west of the Susquehanna, i. 116—ridges, how eroded, ii. 921—ridges, instances, i. 11—Pri. sandst., Churchtown, i. 179—Wightsville to York, i. 223—ridges and valleys, i. 10—rolls or local saddles, ii. 88—north of Singley's farm, ii. 34—S, structure, ii. 166—southern coal-basin, Little Schuylkill, ii. 52—spurs, i. 186—Surg. rocks, Buckstown Mountain, i. 561—south of Tuscarora Hill, details, ii. 107—from Tuscarora to East Norwegian, ii. 90—Beaver Meadow coal-field, ii. 244—valleys, i. 9, 15—structure, i. 16—scenery, i. 30, 116, 527, ii. 941—of depression and erosion, i. 16—of elevation and erosion, i. 16—north of Aunity township, i. 200.
Anticosta, island of, ii. 785.
Anti's Gap, drift-mound, i. 489.
Antietam Creek, white limest., i. 258.
Appalachian chain, i. 5—valleys, i. 15—north-western half, structural features, i. 461—west of the Susq., subdivisions, i. 434—coal-basin, range, &c., ii. 15—subdivisions of strata, ii. 16—coal-field, ii. 954, 959—ocean, revolution in its physical geography, i. 253—Palæozoic basin, ii. 748—ridges proper, on third belt of the second district, i. 7—valleys, contractions and expansions, i. 6—its character, &c., i. 6—lowest level, i. 6—longitudinal outline, i. 6—second belt of the second district, i. 6.
Aquanchicola, Surg. red shales, i. 283.
Appendix to Book VIII., ii. 413.
Aramink Creek, exposure of Pri. rocks, i. 155, 156.
Archibald, ii. 325—coal-seams, ii. 331—main bed, ii. 335—west section, ii. 334.
Areas of coal-basins of Pennsylvania, ii. 465—Missouri coal-field, ii. 965—of coal-fields, ii. 1015—of chief river-basins, i. 41—of great geological groups, ii. 743—once possessed by Pittsburg coal-seam, ii. 800—area of State, i. 2.
Argillaceous sandst., i. 60.
Armagh, ii. 660.
Armenia Mountain at Blossburg, i. 310—Pon., i. 142—Pon. rocks, thickness, i. 300—Pon. strata, i. 142.
Armstrong's Mill, ii. 584—Mine, ii. 375—Valley, i. 114—10th anti. axis in the Pon. rocks, i. 316.
Arnold's Mill, red sandst., i. 223—Pri. slate, i. 185.
Arragonite, west from Kutztown, 1. 251.
Arthrophycus Harlani, ii. 821.
Asbestos in joints of trap-rock, ii. 692.
Ashby-de-la-Zouch coal-field, ii. 980.
Ashland anti. axis, ii. 272—basin, structure, details, ii. 272—and Catawissa road coal-measures, ii. 292—Gap, ii. 147—Ser. series, i. 147—coal-field, ii. 276—series of coals, 274, 275.
Ashton and Tamaqua nortb basin, ii. 30.
Asky's Run, i. 552.
Asplenites, ii. 864.
Asterophyllites, ii. 851, 852.
Astonville, ii. 514—section, ii. 515—conglomerate, ii. 148—Umb., i. 145—Vesp., i. 143.
Atchafalaya Raft, ii. 801.
Atkinson's Mill, Sca. and Prem. limest., i. 417.
Atlantic belt, ii. 767—drainage, i. 40—metamorphic belt, ii. 747—river-basins, i. 41—slope, i. 4, ii. 747—of Pennsylvania, climate, i. 52—physical break, i. 63.
Atrypa, ii. 825—aspira, ii. 828—congesta, ii. 823—eximia, ii. 829—hystrix, ii. 829—intermedia, ii. 823—kævis, ii. 825—limitaris, ii. 826—peculiaris, ii. 825—plicifera, ii. 817—reticularis, ii. 823—unguiformis, ii. 826.
Attleborough, Pri. rocks, see section, i. 152.
Audenried Company's shaft, ii. 385.
Augwick Creek, limest. belt, i. 418—Valley, i. 115, 397.
Augusta Furnace, i. 267.
Aur. arg. limest., near Bern Church, i. 253—east of Jonestown, i. 253—Northkill, i. 253—Rehrersburg, i. 253—from Womelsdorf to Bernville, i. 253—calc. sand., i. 112—at Columbia, i. 123—character and thickness, i. 105—outcrops north of Chester County Valley, details, i. 231, 232—blue limest., ii. 782—iron ores, ii. 722—limestone, i. 92, 116—anticlinals, i. 244—anti. valleys, i. 117—Attleborough, character of exposures, i. 224—basins, i. 176—boundary, i. 257—insulated belts, i. 224—belt in Path Valley, i. 322—south of the Pigeon Hills, i. 222—between Two Top and Little Cove Mountains, i. 262—south of Bethlehem, i. 236—in Blacklog Valley, i. 370—Bucks County, near New Hope, i. 208—near Bucker's Hill, i. 99—Chester County Valley, i. 208—in Chester and Montgomery Valley, i. 111—of Chestnut Hill, i. 242—Chiques Ridge, i. 194—Delaware River, i. 241—between the Delaware and Schuylkill, i. 208—Delaware to the Schuylkill, i. 233, 241—Durham Hill, i. 99—metamorphism, i. 212—fossils, i. 229—south-western part of Franklin County, i. 261—Friend's Cove, i. 507, 508—Keeley's Tavern, i. 200—Kishacoquillas Valley, i. 478—Kittatinny Valley, between the Susquehanna and Maryland, i. 257—Lancaster and York, i. 208, 220—Lehigh and Berks, 196, 197—Lehigh Hills, i. 97, 99—junction at Lehigh with Mat. slate, i. 241—Little Swatara, i. 255—south-west of Lobach's Mill, i. 198—mouth of Martin's Creek, i. 242—near Martin's Creek, i. 243, 244—Neversink Hill, i. 103—Nippenose Valley, caves, i. 490—boundary from Schuylkill to Stouchtown, i. 251—Path Valley, i. 318—Pleasant Valley, at Joel Bailey's, Taggart's Cross-roads, &c., i. 228—quarries near Boalsburg, i. 501—quarries, i. 213—quarries, Swatara, i. 255—quarries, Upper Merrion, i. 213, 214—quarries below Wrightsville, i. 222—quarries near York, i. 222—Myerstown, i. 251—Saucon Creek, i. 234—South Mountains, east of Schuylkill, i. 200—east of Stumpstown, i. 254—subdivisions, i. 471—syn. troughs, i. 94—between Susquehanna and Maryland, i. 258—Upper Milford,

i. 236—Valley of Montgomery and Chester, i. 209—axis of Wolf's Hill, i. 242.
Aur. magnesian limest., i. 111, 112—on the Schuylkill, i. 124—near Bellefonte, i. 470—character and thickness, i. 105—Kittatinny Valley, i. 238—in Kishacoquillas Valley, i. 470—Little Northkill, i. 252—Main Northkill, i. 252—Matsan's Run, i. 165, 166—Valley of Montgomery and Chester Counties, i. 161—south-east district, i. 208—exposure near Strickler's Run, i. 220.
Aur. period, ii. 749—physical geography of, ii. 781.
Aur. rocks, i. 117—Canoe Valley, i. 505—Kishacoquillas Valley, i. 462—Kittatinny Valley, i. 112—South Mountains, i. 112—south-east district of Palæzoic region, i. 111—near Williamsburg, i. 505.
Aur. series, ii. 752.
Aur. strata of Atlantic slope, i. 149—Spring Mill, i. 164, 165—thicknesses of, i. 123, 124.
Austin on structure of south of Ireland, ii. 900.
Avicula, ii. 827, 833—damnoniensis, ii. 829—decussata, ii. 827—flabella, ii. 827—insueta, ii. 820—subplana, ii. 823.
Avondale Tunnel, ii. 412.
Axis-planes, ii. 890—of the flexures, i. 192.
Axes traced, ii. 362, 370.
Ayer's Store, Pri. rocks, i. 173.
Ayrshire coal-field, ii. 984.
Azoic region, west of the Brandywine, i. 158—rocks, i. 64, 167, 168—strata, ii. 744.
Babb's, ii. 362—lot, at Warrior Creek, ii. 391.
Backbone Ridge, Cadent shale, 527—vein, tabulated, details, ii. 196.
Back-track railroad, ii. 49.
Bad Lands, ii. 771.
Bailey's Farm, gneiss in Aur. limest., i. 227—limest. quarry, east of Pine Creek, i. 544.
Bainbridge village, i. 49.
Baird Knob Terrace, i. 482.
Baird's and Stewart's knobs, character of the strata, i. 476.
Bake Oven Knob, position, i. 288.
Bald Eagle canal, exposures of Aur. limest., i. 471—Creek, Cadent olive-slate rocks, i. 552—valley, section at Eagle Furnace, i. 546—mountain, i. 11, 15, 116, 117, ii. 2—exposures of the strata, i. 488—glen from Anti's Gap, i. 491—north-east of Hannah Furnace, i. 553—Levant grey sandstone, thickness, i. 473—Levant red sandstone, thickness, i. 473—near Little Juniata Gap, i. 553—Mat. slates, i. 495—Mer. sand., i. 439—south-west of Milsburg, composition, i. 552—Surg. slates and iron sand., i. 536—profiles of the crest and terrace, i. 553—vegetation, &c., i. 545—opposite Williamsport, i. 15—range, i. 117—ridge, i. 19—valley, comparison of sections, change in the geological structure, i. 551—scenery of, i. 49, 534, 535.
Bald Ridge, ii. 617.
Balliot's iron-ore mines, i. 264—mine, ii. 724—old slope, big coal, ii. 262.
Ball ore, ii. 359.
Baltimore bed, ii. 386, 393.
Baltimore and Carlisle turnpike, i. 204.
Baltimore Co.'s coal. ii. 380—coal-bed subdivisions, ii. 381—mine, ii. 327—old mine anti., ii. 381.
Barclay's Drift, ii. 513.
Barcleugh vein at West Branch, ii. 170.
Bare Ridge, saddles, ii. 33—colliery, ii. 417.
Barn coal, ii. 40.
Barne's Run, ii. 242—coal-basin, 262.
Barnett's coal, ii. 452, 453.
Barnum's Mine, ii. 362.
Barren group, ii. 493, 502, 503.
Barren Hill, i. 73—anti. axis, i. 161—flexure, i. 211—exposure of Pri. rocks, i. 155, 156—Pri. rocks, i. 150, 151—school-house, i. 168, 192.
Barren-measures, ii. 607, 609—Pittsburg, ii. 633.
Barren Ridge foss. limest., i. 497.
Barrens, i. 16, 501, 505, 529—iron ore, i. 499—limestone, i. 494—sandstone rocks, i. 497.
Bartlett's Run, exposure of foss. chert, i. 545.
Bart township, belt of Pri. and Aur. rocks, i. 111—Aur. limest., i. 214.
Basin of the Alleghany and Ohio rivers, i. 35—between anti. F and D, ii. 89—B boundaries, ii. 63—of Big and Little Lick anti., ii. 47—C D ranges, red-ash coals, ii. 104—of Carey's Shaft, ii. 38—D, red-ash coals, ii. 97—D E, coal-beds, ii. 123—west, ii. 141—E F, ii. 123—E G, ii. 141—F G, ii. 91—F G, ii. 123—G H, ii. 124—G H, ii. 142—I J, ii. 143—I K, ii. 124—J K, ii. 143—K, ii. 144—of Lehigh Summit mines, ii. 63—of Little Lick Mountain, ii. 184—M N, on the Swatara, ii. 155—north of the main Griscom Saddle, ii. 45—north of the Great Gate Ridge anti., ii. 35—north of axis H, ii. 92—north of Peach Mountain basin, ii, 112—north of Swatara Falls, details, ii. 42—Q R, details, ii. 181—of Red Mountain, details, ii. 185—between Silver Creek and Mill Creek, ii. 123—Bath iron ores, i, 263.
Basins, ii. 29.
Bast and Pearson's slope, ii. 172.
Bast's red-ash colliery, ii. 431—white-ash coal, Wolf Creek, ii. 171—seam, ii. 427—colliery, ii. 430.
Bathygnathus borealis, ii. 693.
Beach Creek, i. 545—Cadent black slate, i. 551—Scalent rocks, i. 545—mines, ii. 404.
Bean's Cove, i. 15, 117—details of strata, i. 509—station, Cadent and Vergent strata, i. 581.
Beansville, ii. 546.
Bear Creek, i. 290, ii. 521—basin, 188.
Bear Gap, ii. 440—details of, ii, 191—river pass, i. 29—Seral series, i. 146—tunnel, 441—Wiconisco basin, i. 146—meadows, i. 482—mountain, anti. axis, i. 513—iron ore, i. 516—Levant white sandstone, i. 515.
Bear Mountain, i. 25—dip, ii. 27.
Bear Ridge, anti. axis, origin, &c., ii. 268—tunnel, ii. 270.
Bear Run, ii. 664.
Bear Valley, i. 118, 261, 336—basin, iron ore, ii. 190—coal-basin, i. 114—Mat. slate, i. 323—position, &c., i. 323—structure, ii. 179.
Beattie's Gap, ii. 403—Knob, i. 403—syn. exposures of the str., i. 476.
Beatty's station, ii. 618.
Beaumont, Mr, ascribes coal to swampy islands, ii. 805.
Beaver, i. 120, ii. 773—furnace, foss. ore, i. 411—meadow basin, ii. 6—pebbles of conglomerate, ii. 23—anti. axis, ii. 244, 245, 246—coal basin, 240—flexures, i. 286—dimensions, &c., ii. 244—field, i. 303—mine, tabulated details, ii. 250.
Beaver River, i. 52, ii. 491, 567, 574, 580, 581—basin, i. 42.
Beaver Run, i. 422.
Beavertown, foss. ore, i. 410—syn. knob, i. 405.
Beck's Mill marble quarry, i. 214.
Becraft's Mount, ii. 785.
Bedford, i. 117—anti. flexure, i. 510—Cad. and Verg. rocks, i. 568—county, mono. valley, i. 19—Sca. limest., i. 539—Surg. and Sca. rocks, i. 538.
Bedford and Greensburg turnpike, i. 565.
Bedford, section, i. 569—springs, section, i. 568—turnpike, Sugar-loaf Hills, i. 562.
Beech Creek, ii. 481, 530.
Beech Grove, ii. 318.
Beechem's tunnels, ii. 110—Upper tunnel, ii. 414.
Behe's Creek, ii. 380—pond, ii. 379—axis, ii. 382.
Beisel's ore mine, ii. 723.
Belfast coal, ii. 139, 140.
Belgium, ii. 990.
Bellefonte, i. 486—Gap, Levant series, i. 127, 129, 130—Levant grey sandst. i. 127—Mat. rocks, i. 497—turnpike, Cad. lower black slate, i. 425—Prem. limest. i. 417.
Bellerophon bilobatus, ii. 819.
Belleville, Mat. slate or shale, i. 478.
Bellman's tavern, slate and limest. quarries, i. 455.
Bell's Hill in anti. axis, i. 349—Mer. sandst., i. 353—Surg. and Sca. marl group, i. 341.
Bell's limest. quarry, i. 283—sawmill, i. 513—ore-bank, Owen's Ridge, i. 427—ore-bank, i. 423.
Belmont, ii. 417—Lewis and Spohn coals, ii. 129—Lewis vein, ii. 124—Pon. rocks, i. 305—slope, ii. 129.
Belts in anthracite region, i. 118—5th of Aur. limest., i. 230—1st of Aur. limest., i. 225—in 1st district of Palæozoic region, i. 111, 112—4th of Aur. limest., i. 229—of limest. and slate, Franklin county, i. 261, 262—2d Aur. limest., i. 226—of serpentine and steatite, i. 167—6th Aur. limest., i. 231—6th district, Upper Juniata and west branch Susquehanna, i. 116—3d of Aur. limest., i. 226.
Belvernon, ii. 642.
Bellevue mines, ii. 350.
Benedicts, ii. 362.
Bennett's branch, ii. 482—section, ii. 483, 539—Big Coal axis, ii. 367—northern anti. axis, ii. 112
Bennett or Patton's coal-bed, ii. 410—coal, ii. 408.
Bennett's southern anti. axis, ii. 112—Upper Peach Mountain vein, ii. 91.
Bennington, ii. 652.
Bergman's Run anti., ii. 392—Gulick's Gap, ii. 397.
Berks county, Pri. white sandst., i. 196—metamorphic rocks, i. 97.
Berlin, ii. 494—coals at, 651.
Berry's Mountain, i. 1112—Knob, i. 118—mono. crest, i. 14—Pon. red sandst., i. 363—Vesp. and Umb. rocks, i. 365.
Berwick Reach, ii. 5.
Bethany, ponds with pure sand, i. 304.
Bethel Hill anti. flexure, i. 211—cleavage, i. 172—Pri. rocks, i. 162.
Bethlehem turnpike anti. wave, i. 162—from Sandy Run to Chestnut Hill, i. 164.
Bettinger's Mines, Little Muddy Creek, ii. 177—Southern Mines, ii. 167—Tunnel, ii. 437.
Beury's Colliery, ii. 433.
Beyrichiæ, by T. R. Rupert Jones, ii. 834.
Beyrichia lobatus, ii. 820—Maccoyana, ii. 824—Pennsylvania, ii. 824.
Big Beaver Creek, Aur. limest., i. 211—Pri. slates, i. 176, 177—limest. basins, i. 217.
Big Black Creek coal-basin, ii. 242—basin, anti., ii. 261, 262.
Big Coal Beaver Meadow Basin, ii. 111, 131, 242, 246, 103, 415, 147—basin, ii. 331—Hazleton Basin, ii. 257, 258, 259—Jeansville slopes, ii. 249—Main Black Creek, ii. 263—outcrops, ii. 262, 263—outcrop in Palmer tunnel, Main Big Creek, &c., ii. 104—Panther Creek tunnel, No. 9, ii. 75—On De Long Track, ii. 216—Donaldson, ii. 232—Lawton's Old Colliery Gap, ii. 202, 203—Summit Mines, ii. 69—Silver Creek, ii. 120—thickness in tunnel, No. 5, ii. 74—Thick Mountain, ii. 181—tabulated details, ii. 354.
Big Creek, ii. 414, 436—basin, grey-ash coals, ii. 87—elevation of Ser. conglomerate, ii. 106—coal-beds, ii. 200—coal, ii. 85.
Big Diamond anti. axis, ii. 38—coal, ii. 137—West-west Branch, ii. 119, 153—bed, ii. 39—West Branch, &c., ii. 218—south of Carey's shaft, ii. 134—slope, ii. 432.
Big dirt-bed, ii. 38.
Big Fishing Creek, i. 485, 492—character of strata, i. 495.
Big Flats, tabulated details, ii. 198.
Big Gate coal-bed, ii. 117.
Big Hazelton coal-bed, ii. 256.
Big Juniata, Mat. slates, i. 500.
Big Lick Mountain dip, ii. 27—anti. axis, ii. 45, 162—of Donaldson, ii. 163—red-ash coals, ii. 164—anti. axis, ii. 182.
Big Mountain, i. 481, 482, 528—anticlinal, ii. 267—anti. west of Kleckner's, i. 489—white sandst., i. 487.
Big Mine Run, flexures and coals, ii. 275—anti. axis, ii. 277—coal-measures, ii. 271.
Big Marsh Creek, ii. 525.
Big or North Gate coal, New Philadelphia, ii. 220.
Big Pittston coal, ii. 363.
Big Quaker Run, ii. 287.
Big Rock, ii. 462—coals shafted, ii. 179.
Big Seam, slope mining, ii. 56—Pinebrook, ii. 351—south-east of Pinebrook, ii. 352—Diamond Mine shaft, ii. 354.
Big Sandrock coal, Mill Creek, ii. 135.
Big Scrub Ridge, Cad. and Verg. rocks, i. 428—Pon., Vesp., and Umb. rocks, i. 430, 431—Vesp. conglomerate, i. 324.
Big Slope vein, Eaton and Carter, ii. 78.
Big Spring limest. quarry, i. 282.
Big Tomhicken basin, ii. 255.
Big Tracey coal, ii. 95, 121—drift, ii. 142, 143, 136, 118, 119, 145, 219—anti. axis, ii. 39—East Norwegian, ii. 96.
Big and Little Tracey coals, anti., ii. 34.
Big vein, in basin D F, ii. 109—Swatara, ii. 178.
Big white-ash coal, west of Casca William tunnel, ii. 87—Paterson basin, ii. 110.
Big Will's Creek, Mer. sandst., i. 571.
Binney, proved Stigmaria to be root of Sigillaria, ii. 803.
Bird-tracks, ii. 694.
Birmingham Mat. and Aur. rocks, i. 503—Mat. valley, i. 555.
Birmington, dip of Levant rocks, i. 488.
Bishop's Creek, Aur. limest., i. 199.
Bison, i. 51.
Bitter Root Mountains, ii. 747.
Bituminous coals, ii. 994—coal-basins north of the Conemaugh and Ohio, ii. 480—south of the Conemaugh and Ohio, ii. 493—fields, i. 466—western portion of northern table-land, i. 35—northern belt, i. 35—(older) coal-measures, ii. 18—Rausch Gap, ii. 196.
Bituminous coal region, i. 33—northern belt, i. 34—composition, i. 119—boundaries, i. 119.
Bituminous coal region, structure of the country, i. 117—strata, ii. 474—strata limits, ii. 15.
Bixler's mill, i. 351, 359—fifth anti. axis in Cad. rocks, i. 315.
Bixler's tavern, marble quarry, i. 490.
Blackband iron ore, ii. 359.
Black Creek, ii. 242, 399—coal-fields, ii. 12—Ridge, ii. 242.
Black Bog, i. 21.
Black Heath bed, John Dougherty, ii. 168.
Black Heath coal, ii. 131, 427, 137, 416—bed, ii. 109—and Big coal, Dundas colliery, ii. 168—Wolf Creek, ii. 171—Thick Mountain, ii. 181—Staunton's tunnel, ii. 209—Casca William, &c., ii. 216—synonym, ii. 222—Donaldson, ii. 232.
Black Hills, ii. 764.
Black Hole Creek, i. 456.
Black Horse Hill, i. 179—tavern, steatite and serpentine, i. 169.
Black Knob, i. 559.
Black Lick Creek, ii. 589, 590, 660.
Black Lick River, i. 33.
Blacklog Creek, i. 371—anti. valley, i. 115—mountain, i. 364, 366, 367, 377, 419, 115—position, range, i. 370—Surg. slates and Sca. marls, i. 414—valley, i. 9—axis, i. 373—anti. axis, i. 397—anti. axis, i. 419—axis, Cad. and Verg. rocks, i. 392—Prem. chert, i. 388—Sca. and Prem. limest., i. 384—composition, i. 369, 370.
Black Marsh, i. 454.
Blackman's coal-seams, ii. 33.
Blackman's slope, ii. 393.
Black Mine coal. ii. 139, 140—Oliver's colliery, ii. 127—Salem colliery, ii. 175—West Branch, &c., ii. 220.
Black Mine slope, ii. 426.
Black Mine vein, ii. 117.
Black Oak Ridge, composition, i. 561—Sc. and Prem. limest., i. 525—Surg. ore group, i. 557.
Black River and chazy limest., ii. 752.
Black Valley, i. 522, ii. 137, 157—Casca William, &c., ii. 217—John Dougherty's, ii. 168—Mine Hill, anti. F, ii. 169—Thick Mountain, ii. 181, 109—St Clair, ii. 132—upper white and grey-ash group, ii. 18—Wolf Creek, ii. 171—bed, ii. 415—seam, ii. 416, 427, 429.
Black Spring Gap coal, ii. 195.
Blair county, mono. valley, i. 19—Sca. limest., i. 539—Surg. and Sca. str., i. 538.
Blair's Valley, anti. belt of limest., i. 261.
Blairsville, ii. 485, 502—sections near, ii. 600.
Blake, W. J., researches, ii. 773.
Blockhouse Branch, ii. 517.
Blodgett's, Mr Lorin, Treatise on the Climatology of U.S., i. 55.

Bloody Run, i. 522—village, i. 525.
Boomfield, 8th anti. axis, i. 315—13th anti. axis, i. 316—boundaries, i. 340—Cad. and Verg. rocks, i. 359—Sca. and Prem. limest., i. 348—Sca. and Prem. limest., i. 349.
Bond's coal-beds, ii. 555.
Bone coal, ii. 991.
Bony coal, Lawton's old colliery gap, ii. 202.—Mine Hill Gap, ii. 169—Newkirk tunnel, ii. 101—seam, ii. 414—Sando's colliery, ii. 207—Tamaqua, ii. 76—Tamaqua, ii. 79.
Book IX., ii. 466.
Boon's road, ii. 483, 526.
Bordentown, i. 48.
Border's Black Heath colliery, ii. 430.
Boring for coal, ii. 1009—on Gaylord's land, ii. 411—Powderly Creek, ii. 332—opposite Providence, ii. 355.
Bosbeshell coal, ii. 128.
Boston Colliery Company, ii. 225.
Boulder-drift, ii. 774.
Boundary of red sandstone, ii. 676—of Lower Missouri coal-field, ii. 965.
Boulder-drift in the 5th district, i. 39—matter, its distribution, details, i. 37.
Boundaries, i. 1—of rocks of South Mountains, i. 92.
Bower's Mountain, i. 316, 318—13th anti. axis, i. 316—axis, ore and iron sandst., i. 341—Levant sandsts., i. 333—ridge of Surg. rocks, elevation, i. 340.
Bowman's Mountain, i. 121.
Bowman, Mr, on subsidence of land in coal period, ii. 805.
Bowman's and Richardson's slope, ii. 100.
Bowman's slope, ii. 102—slope, Reinhardt's Run, ii. 216, 99.
Boyerstown, i. 200.
Brachyphillum, ii. 876.
Bradford, i. 120—county, Verg. rocks, i. 140, 141—Verg., flags, ripple-marks, i. 295.
Brady's mill, ii. 602, 603.
Branch basin, south of Kennet Square, i. 226.
Branchdale colliery, ii. 162—Muddy Branch, ii. 176, 436.
Branchdale Lewis Vein axis, details, ii. 162—slope, axis, ii. 160.
Branches of Wheatley lode, ii. 704.
Brandy Camp Creek, ii. 541, 543—road, 541.
Brandywine, Gneissic rocks north of Chad's Ford, i. 76—older Pri. slates, i. 158—Pri, slates, i. 77—river basin, i. 41—West Branch Pri. series, i. 174.
Brant's ore-bank, i. 337.
Brayler coal, ii. 109.
Break between Auro. and Mat. periods, ii. 783—at close of Mat., ii. 786—in the str., ii. 749.
Breastwork Run, i. 565.
Breinig's mine, ii. 725.
Bloomfield Valley, Surg. and Sca. rocks, i. 340, 341.
Bloomsburg Iron Company, i. 445, 446—limest. quarries, i. 451—Prem. limest. i., 438.
Blossburg, ii. 519, 521—coal-basin, ii. 15—coal-field, ii. 484—Ser. series, i. 148—strata, ii. 520—Umb. series, i. 145—Vesp. rocks, i. 143—Vesp. and Pon., ii. 522.
Blue Hill, Cad., Verg., and Pon. rocks, i. 402—Northumberland scenery, i. 49—Pon. red sandst., i. 397—structure, i. 502—syn. trough, i. 403.
Blue Knob, Pon. rocks, i. 559.
Blue Mountain, i. 7, 11, 287, 288, 289, 334, 335, 343, ii. 3—anti. flexures, i. 289—Indian Gap, i, 293—Levant white sandst., i. 344—Monody Gap, i. 293—south of Pine Grove, i. 293—Surg. iron sandst., i. 344—Swatara Gap, i. 293—topography, i. 290.
Blue and Second mountains, details, i. 292.
Blue Ridge, i. 12, 21, 115, 362, 377, ii. 4—anticlinal, i. 115—anti. axis, i. 368—anti axis, i. 419—anti. axis, i. 423—axis, Surg. str., i. 376—Cad. and Verg. belt, i. 361, 367—Pri. str., i. 203—scenery at Potomac River, i. 6—structure, composition, i. 369—Sugar Valley, i. 50—Surg. and Sca. str., i. 413.
Blue rock, ore sandst., i. 414.
Boalsburg, i. 494, 499—Stone Valley, i. 514.
Boardley Run, Aur. limest., i. 230.
Board Yard Basin coal-beds, ii. 254—Hazel Creek Valley, ii. 241.
Bob's Creek, i. 559—Buckstown, i. 563.
Bog iron-ore, ii. 548, 549, 553, 557, 558, 562, 563, 568, 569, 571.
Bony coal, north of the Dutchman's Seam on Mill Creek, ii. 204.
Brightfield's Run, Cad. black slate, i. 425—Surg. foss. ore, i. 432—syn. trough, i. 421.
Brighton, ii. 492—Old, ironworks, ii. 580, 581—New, ii. 581.
Brinton's Ford, micaceous gneiss, i. 82.
Bristol coal-field, ii. 979.
British coal-fields, ii. 977.
Broadhead's Creek, i. 283—cleavage, i. 285—rocks exposed, i. 272, 273—Prem. limest., i. 136—red shale, i. 280—Post-mer. rocks, i. 282—Verg. flags, i. 285.
Broad Mountain, i. 114, 482, ii. 6—anti. flexures, ii. 223—coal-basin, i. 286, ii. 21—small coal-basins, ii. 225—coal conglomerate, ii. 6—outcrops of lower white-ash group, ii. 202—slope, structure, and contents, ii. 203—colliery, ii. 438.
Broad Mountain, composition, structure, i. 118—Surg. shales, i. 515.
Broad-Top Basin, Umb. series, i. 145.
Broad-Top coal-fields, ii. 448.
Broad-Top Improvement Company's bed, ii. 453.
Broad-Top Mountain, i. 529, 512—anti. axis, i. 513—anti. flexures, i. 532—coal-basin, bituminous coal-measures, i. 116—bituminous coal-field, ii. 24—coal-field, ii. 15—Ser. series, i. 148—syn. troughs, i. 532 syn. belt, ii. 4—Umb. rocks, details, i. 531.
Broad-Top region, topography, i. 528.
Brockville basin, north east, ii. 31.
Brokenstraw Creek, i. 577, 578, ii. 557.
Brookdale mine, ii. 705—lode, ii. 701.
Brookland furnace, i. 421—bank, i. 432—Sca. and Prem. limest, i. 417—ore-bank, pipe-ore, i. 479.
Brookville, ii. 487, 583.
Brookville coal, ii. 490, 496, 568, 570, 573.
Brookville and Clarion coals, ii. 490.
Brookville, Clarion, and Kittatinny coals, ii. 488.
Brookville and Clearfield turnpike, ii. 485.
Brookville and Curwinsville turnpike, ii. 544.
Brookville turnpike, ii. 486.
Brongniart, researches by, on stigmaria, ii. 803.
Brown's cannel coal, ii. 585—coal, details, ii. 59.
Brown's colliery, Primrose coal, ii. 147.
Brownfield's bank, ii. 624.
Brown, Mr, cited, ii. 952.
Brown's Gap, Aur. limest., i. 478—iron ore, i. 412—Surg. rocks, i. 412—streams in limest. strata, i. 476—Mat. shale, slate, and sandstone, i. 478.
Brown's limest. quarry, i. 225.
Brown's lower slate quarry, details, i. 188, 189.
Brown's mill, exposures of Aur. limest., i. 471.
Brown's Oak Hill, slopes, ii. 425.
Brown's Run, i. 340, ii. 645.
Brownsville, ii. 642.
Brownsville axis, ii. 613—east of section, ii. 643—Pri. rocks, i. 152—to Uniontown, ii. 644, 645, 646, 647.
Brush Creek, ii. 580.
Brush Creek Valley, Umb. series, i. 145—iron-ore, i. 529—Umb. limest., i. 530—Vesp. rocks, i. 533.
Brush Mountain, i. 15, 482, 484, 492, 553—structure, i. 483—South Terrace Ridge, i. 484—syn. axis, i. 494—syn. spur, i. 13.
Brush Valley, i. 116—anticlinal, i. 484, 485—axis, i. 466, 499—dips of the strata, i. 494, ii. 4—limestone, i. 492—Narrows, i. 484, 459—dip of the rocks, i. 487.
Bucania trilobatus, ii. 822.
Bucher's Hill, character of the gneiss, i. 99.
Buckland, Dr, on stigmaria, ii. 803—views of origin of coal, ii. 805—anniversary address cited, ii. 806.
Buck Mountain colliery, ii. 261—Company, ii. 241—coal-basin, ii. 252—Company's basins, ii. 253—Creek, ii. 243.
Buck Ridge, 7th anti. axis, i. 315, 332—ore sandst. i. 339—anti. axis, ii. 209, 210, 281.
Buck Run, ii. 308—anti. axis, ii. 282, i. 84—coal, ii. 283—exposures of coal, ii. 281, 289—lower coal-measures, ii. 279—trap-rock, i. 170.
Bucks County, thickness of Pri. rock, i. 155.
Buckstown, i. 507—Cad. strata, i. 564—Mountain, Surg. strata, i. 560—olive shales, i. 559.
Buckville, details of coals, ii. 215, 216—breaker, syn. axis of basin C, ii. 102—tunnel, see Fig., ii. 102.
Buffalo Creek, ii. 487, 596—Mer. sandst., i. 351—Pon. red sandst., i. 363—Sca. and Prem. limest., i. 347—Surg. strata, i. 338—Valley, i. 114.
Buffalo and Christman's valleys, anti. axis, origin, range, composition, i. 464.
Buffalo Furnace, ii. 595.
Buffalo Gap, Mer., i. 571.
Buffalo Mountain, i. 23, 118, 485, 510—flexures, i. 454—Lev. sandst., i. 483—mono. crest, i. 14—position, i. 457—Pon. red sandst., i. 363—scenery, i. 51—structure, i. 364—Surg. rocks, i. 453.
Buffalo township, Cad. and Verg. rocks, i. 357.
Buffalo Valley, i. 482, 116, 485—Cad., Verg., and Pon. rocks, i. 452—range, dimensions, i. 456—Sca. variegated marls, i. 437—Surg. shales and Sca. marls, i. 458.
Buffington's Mines, ii. 594.
Buhrstone, ii. 491—or chert, ii. 568.
Building-stone in Erie and Crawfurd counties, details, i. 583.
Bull engine, ii. 444.
Bullet's Run, Mer. sandst., i. 547.
Bunbury, Mr, ii. 842.
Bunker Hill, ii. 548, 550—Aur. limest., i. 254—sandstone, i. 254.
Burns's Valley, i. 318, 332—5th anti. axis in Mat. slates, i. 315—Mat. slate, details, i. 321.
Burnt Cabins, i. 387, 394—Cad. black slate, i. 393, 394—Mer. sandst., i. 390—Surg. and Sca. rocks, i. 382.
Bushy Creek, ii. 32.
Bushkill cascade, i. 280—gap, i. 95.
Bushy railroad anti. axes, ii. 112—compass-line, ii. 111.
Bushy tunnel, ii. 104.
Bushy Valley, ii. 111—anticlinal, ii. 31.
Buthotrephis gracilis, ii. 822.
Butler, i. 120—basin, ii. 366—Creek anti., ii. 382.
Byer's coal, ii. 619.
Cabin Branch Run, syn. valleys, i. 186.
Cacoosing Creek, Pri. rocks, i. 202—trap-dyke, i. 251.
Cadent black slate, i. 420—basin of, i. 427—Dale's Hill, i. 460—in the fourth syn. belt, i. 424—near Huntingdon, i 520—iron ores, i. 401, 432, 433—north-west of Lewistown, i. 426—Waterloo Gap, i. 389.
Cadent lower black slate, i. 355, 425—fossils, thickness, &c., i. 107—Kittatinny Valley, i. 138.
Cadent olive shale, Muncy Hills, i. 540.
Cadent olive slates, Jerseytown to Fruitstown, i. 454.
Cadent period, ii. 749.
Cadent rocks, i. 113—in Bald Eagle Valley, i. 540—Gladding's Run, i. 572—north of Lehigh water-gap, i. 274—Lewistown Valley, i. 406—Perry county, i. 351, 352, 355, 356—Susquehanna Gap, i. 276.
Cadent sandst. near Meadville, i. 584.
Cadent series, ii. 755—physical geography of, ii. 791.
Cadent shale group, Tuscarora syn., i. 390—fossils, character and thickness of, i. 108—Perry County, i. 356—south-east side of, i. 139—Little Cove, i. 419.
Cadent slates and shales, i. 280—Whitedeer Hole Valley, i. 456.
Cadent strata, i. 114—Carpenter's Point to Walpack Bend, i. 280—thickness of, i. 138, 139, 140.
Cadent upper black slates, i. 275—fossils, character and thickness, i. 108—on the Lehigh, i. 139.
Cadent and Verg. rocks, Blacklog Mountain, i. 427—south-west of Buckstown, i. 563—character of the soil in the north-west district, i. 585—south-west of Evit's Creek, i. 570—Fulton County, i. 428—south-west of Hollidaysburg, i. 559—Lewistown Valley, i. 399—north of Milesburg, i. 552—Muncy to Milesburg, i. 548—Owen's and Chestnut ridges, i. 426—west from Pine Creek, i. 551—north-western district, i. 576—Tuscarora syn., i. 390—Woodcock Valley, i. 523.
Cainozoic deposits, ii. 767.
Caking coal, ii. 994.
Calamaria, ii. 849.
Calahan's section, ii. 33.
Calamites, ii. 841, 849—species of, ii. 850.
Calcareous conglomerate, lower, ii. 679—upper, ii. 681—traced south-west of Susquehanna, ii. 682, 684.
Calcareous marl in Erie and Crawford counties, i. 586.
Calciferous sandst., ii. 752.
Caldwell's furnace, i. 165—mill, limest. quarry, i. 458—slate quarry, i. 189.
Caledonia, ii. 484, 538, 539—furnace, i. 268—furnace and altered rocks, sandst. ridges, i. 206—ore-bank, i. 269.
Calender coal-seam, ii. 336.
Californian Pleistocene beds, ii. 773.
Callensburg, ii. 572.
Calamine in Aur. limest., i. 101.
Calymene Beckii, ii. 820—bufo, ii. 829—Clintoni, ii. 823.
Calypteris, ii. 865.
Cambrian equivalents, ii. 785—series, ii. 749.
Campbell's Ledge, ii. 326.
Camphill Pri. rocks, i. 81—belt, i. 159.
Canis Haydeni, ii. 773—sævus, ii. 773—temararius, ii. 773—vafer, ii. 773.
Cannel coal, ii. 583, 585, 995—profits of, ii. 596.
Canoe Hill, Lev. sandst., dip, i. 556.
Canoe Mountain, i. 15—anticlinal, i. 50, 554—fault, i. 504—Gap, Lev. series, i. 127, 129, 130—Juniata, displaced summits of, i. 556—Lev. sandst., i. 556—pictorial sketch, i. 13—section of the strata, i. 556—Sinking Valley, pictorial sketch, i. 13—syn. spur, i. 13—syn. flexure, i. 503.
Canoe Place, ii. 483, 548.
Canoe Valley, i. 50—anti. axis, i. 468—Aur. rocks, anti. axis, i. 504—structure at Morison's Cove, i. 506.
Canonsburg, pictorial sketch, i. 36.
Canton Corners, ii. 483.
Cape Breton County coal-field, ii. 953—Island coal-field, ii. 951.
Capon axis, Sca. marls, thickness, i. 398—Surg. rocks, shale, i. 134—thickness, i. 398.
Capon River, Prem. rocks, thickness, i. 399.
Carbonate of copper near Duncan's Point, i. 187.
Carbon Creek, ii. 482, 512, 513—limest. quarries, i. 309.
Carbondale, ii. 318—coal-measures, ii. 331—conglomerate, ii. 330—Great Bed, ii. 332—and Archbald district, details of the coals, ii. 329.
Carboniferous formations, ii. 750.
Carbon Run, ii. 287, 305—anti. axes, outcrops of coals, ii. 289—coal-measures, ii. 291.
Carcharodon, ii. 769.
Cardiocarpon, ii. 876.
Cardita planicosta, ii. 769.
Carlisle Barracks, winds, i. 57—ironworks, iron ores, i. 266, 267—organic remains, i. 239.
Carmichael, ii. 646.
Carpenter's Point, i. 47, 113—Run, aspect of the Surg. and Sca. strata, i. 542—Run, ii. 520—Run, Pon. strata, i. 549.
Carpolithes, ii. 877.
Carrick furnace, iron ore and limest., i. 269—ore-bank, fault, i. 322.
Carrol's quarry, Cad. sandst., i. 583.
Carter's new slope, coal F, dip, ii. 68—slope mine, ii. 83—coal F of Tamaqua, ii. 215—north-east of Tuscarora village, ii. 108.
Cartersville, section at, ii. 516, 517—Ser. series, i. 148—Umb. series, i. 145—Vesp. rocks, i. 143.
Carey's mine, ii. 391.
Carey's slope mine, ii. 422.
Carey's Run, ii. 396.
Carey's shaft, tabular form, ii. 133, ii. 423.
Cascade near Erie, structure of the Verg. flags, i. 582.
Casca William, &c., anti. axis, details, ii. 31—Diamond group of coals, ii. 87—Big coal, ii. 108, 216—coal, ii. 118—Creek, ii. 32—coals in basin D F, ii. 109.
Casca William to Mill Creek, structure and contents

of the basin, ii. 88—Peach Mountain coal, ii. 34—collieries, ii. 85—White-ash colliery, ii. 31, 415.
Cassiday's colliery, ii. 433.
Cashtown conglomerate, i. 206.
Castello's Run, ii. 461.
Castleman's River, i. 33, ii. 494, 658, 659.
Catalogue of coal-plants of North America, ii. 878-884
Catawissa, i. 48—Creek, ii. 7—Mountain, i. 11, 23, 118—crest, i. 15—Pon. rocks, i. 115—Pon. red sandst., thickness, i. 400—Pon. strata, i. 142—red shale, ii. 246, 247—ridge, anti. range, details, ii. 240—road, lower coal-measures, ii. 283—Verg. rocks, i. 140, 141, 439, 580—Vergent shales, thickness, i. 297—Vesp. rocks, i. 143.
Catopteris, ii. 694.
Catskill group, ii. 756—Mountain, i. 47—Pon. strata, i. 113.
Caulopteris, ii. 869.
Cave at Antietam Creek, i. 258.
Cedar Run, i. 340—sync. point, i. 348.
Cedar Spring, i. 384—north-west limit of Surg. and Sca. marls, i. 378.
Cellar coal, ii. 145.
Centemodon, ii. 695.
Central anthracite ridge, ii. 310—railroad section described, ii. 478—tertiary Tracts, ii. 768.
Centre County, oolitic limestone, i. 238.
Centre furnace, Lev. grey sandstone, i. 486.
Centreville, ii. 542—Sca. limest., i. 401.
Certolites ornatus, ii. 820.
Cervus Warreni, ii. 773.
Chadd's Ford, Aur. limest., i. 81—gneiss rocks, i. 81—older Pri. slates, i. 158—Pri. sandst., i. 81,
Chadwick's coal, ii. 108—mine, ii. 415—Tuscarora breaker and Brockville anti. axis, details, ii. 31.
Chætetes lycoperdon, ii. 818.
Chaleurs Bay, ii. 945.
Chamberlain's Hill iron ore, i. 459.
Chambersburg and Gettysburg turnpike road, i. 205, 206.
Chambersburg Mat. limest., i. 259—organic remains, i. 233.
Changes of the sea-bottom, ii. 776.
Charles Hill's colliery, ii. 205.
Charles Miller's slope, on Mine Hill, ii. 147.
Charley Pott coals, ii. 32, 113, 114, 125—at Milford colliery, &c., details, ii. 218—vein, ii. 95.
Charlestown, i. 185—mine, ii. 676.
Chasm filled with Mesozoic conglomerate, ii. 682.
Chatham's Run, hill of Cad. olive shales, i. 551.
Chatauque Lake, New York, i. 39.
Chazy and Black River limest., ii. 782.
Cheat River coal-measures, ii. 957.
Chemical constitution, &c. of coals of North America, ii. 969, 976.
Chemung group, ii. 756—River, i. 48.
Chenoweth coal, ii. 145.
Cherry coal, ii. 995—Creek, Surg. red shales, i. 283—hollow anti., i. 283.
Chert in the coal strata, ii. 14.
Chesapeak Bay, i. 49, 190.
Chester County lead-mine, ii. 676—Poorhouse limest. quarry, i. 230—Creek, i. 70—furnace, i. 421.
Chester and Lancaster Valley, local limest. basins in the main syn. trough, i. 217.
Chester County Pri. rocks, i. 60.
Chestnut coal on Mill Creek, ii. 137.
Chestnut Grove furnace, ii. 690.
Chestnut Hill, i. 123, ii. 690—exposures of Pri. rocks, ii. 156—gneissic belt, i. 96—gneissic rocks, i. 94—iron-ore bank, i. 183—north of Easton, Aur. limest., i. 241—ore-bank, i. 182—Pri. rocks, i. 77, 242—serpentine belt, i. 167—Pri. series, i. 123—steatite and serpentine, i. 71.
Chestnut Ridge, i. 3, 32, 33, 120, 367, 421, 423, ii. 493—axis, Cad. strata, i. 563—iron ore of the Mer. sandst., i. 432—limest. belt, i. 417—Pittsburg seam, section, ii. 614—range, composition, iron ore, i. 563—Surg. rocks, i. 374—Umb. series, i. 146—last outcrop of Vesp. and Umb., ii. 473—west base, ii. 615—views from the western brow, i. 34.
Cheyney ore-bank, ii. 464.
Chiegnecto Cape, ii. 947.
Chilcoat's Sca. and Prem. limest., i. 522.
Chillisquaque Ridge, Cad. and Verg. rocks, i. 454—Cad. older black slate, i. 454.
China earth, i. 69.
Chinchelamoose, ii. 482.
Chiques Ridge, Aur. limest., i. 221,222—crags, i. 49—Pri. rocks, i. 111—origin, range, structure, i. 193—Pri. rocks, i. 176, 194.
Chivington mine, ii. 463.
Chondrites, ii. 848—antiquus, ii. 841.
Chœropotomus, ii. 771.
Christman's Valley, anti. axis, i. 464, 480, 481—Aur. limestone, i. 478.
Church coal, in Sando's colliery, ii. 207.
Church Hill at Tuscarora, red-ash coals, ii. 107—Ridge anti. flexure, i. 211—Primal rocks, i. 163.
Clackmannan coal-field, ii. 985.
Clairville, character of the country. i. 527.
Clarion, ii. 487—coal, ii. 490, 567, 570, 574, 594—group, ii. 490, 573—river, i. 120, ii. 486, 553, 572.
Clarissa furnace, Cad. slates, i. 288—Post-mer. limest., i. 286.
Clark's Knob, i. 318, 336—Lev. sand., i. 333—Mat. slate, i. 323—Surg. slates, i. 344.
Clark's mine, ii. 338—Lackawanna basin, ii. 355.
Clarkson coal, ii. 32, 113, 114, 125, 136, 145—Milford colliery, &c., ii. 219—on Singley's farm, ii. 137—Mr, of Carbondale, ii. 835, 847.
Clarksville, ii. 561—Cad. sandst., i. 584—Vesp. and Pon. rocks, i. 303.
Classification of coal, ii. 988—the coal-seams, i. 226—orographic structure, ii. 917.
Clathopteris, ii. 694.
Claylick Mountain, Mat. slate belt, i. 261.
Clearfield Creek, ii. 483, 533, 537.
Clear Ridge, Cad. and Verg. rocks, i. 527—Verg. flags, i. 522—Verg. shales, i. 427.
Cleavage in Aur. limest. south of the Lehigh, i. 245—north of Easton, i. 245—north foot of Bethel Hill, i. 172—at Columbia, i. 221—from the Delaware to the Lehigh, i. 247—near Delaware Water-gap, i. 273—dip, i. 191—near Easton and the South Mountains, i. 244—and foliation, how viewed by geologists, ii. 907, 908—near Kreidersville, i. 247—laws of, ii. 903, 904—in limest. south of Maiden Creek, i. 102—north of Nazareth and Bath, i. 247—along Martin's Creek, i. 247—planes in Mat. limest., i. 247—in 1st District of Palæozoic region, i. 111—at the Lehigh Hills, i. 98—Mat. slate, i. 247—planes in Pri. rocks, Susquehanna River, i. 186—in 2d district, i. 112—in altered Pri. str., i. 153, 190—slate quarry at Delaware Water-gap, i. 248—slaty, in Appalachians, ii. 902—planes of plication, i. 188.
Clepsisaurus, ii. 693, 695.
Cliff Hill, south of Wellsville, ii. 547.
Clifford's Tavern, Laurel Hill, i. 34.
Climatology of Pennsylvania, i. 52.
Cline's Run, i. 185.
Clinton coal, ii. 136—group, ii. 753—mono. valley, i. 19—Clippinger iron ore, i. 268.
Clover Creek, i. 506.
Coal in direct contact with marine limest., ii. 804—history of, as fuel, ii. 1012—intimate structure of, ii. 800—lands and forest-lands compared, ii. 1017—methods of searching for and mining, ii. 1007—origin explained, ii. 806—near Richmond, Virginia, ii. 763—trade of Pennsylvania, ii. 1018—of tunnel, ii. 61—under the conglomerate, Cool Spring furnace, ii. 472—where found, ii. 948—its composition, classification, &c., ii. 988—A, at the foot of Locust Mountain, ii. 78—of Tamaqua, details, ii. 213—B, Tamaqua, details, *ib.*—C, red-ash coal, ii. 101—C of Tamaqua, ii. 213—D, outcrops, details, ii. 103—D of Tamaqua, details, ii. 214—E, ii. 101, 102—E of Tamaqua, ii. 214—F, ii. 79—F, dimensions at Newkirk tunnel, ii. 101—F of Tamaqua, ii. 101, 215—K, red-ash coal, ii. 81—L, *ib.*—M, details, *ib.*—N, details, *ib.*—O o, *ib.*—O, thickness, *ib.*—P, dimensions, ii. 82—Q, compression of the rocks, *ib.*—Q Q, *ib.*—R, thickness, quality, *ib.*—S, *ib.*
Coals, Buckville tunnel, ii. 98, 102—Coal-run Ridge, ii. 300—economic rank of, ii. 1000—in axis B, ii. 97—axis F, ii. 89—and flexures on West-west Branch, ii. 172—above Green Park seam, Mill Creek, ii. 137—Mount Carmel basin, ii. 280, 281—axis C, Little Schuylkill to Mine Hill, ii. 105—axis H, middle red-ash group, ii. 92—at Middleport, ii. 115—of North America, chemical constitution of, ii. 969, 976—Panther Creek tunnels, ii. 74—Peach Mountain, ii. 95—Red Ridge, ii. 285—Roaring Brook, ii. 339—Roaring Brook basin, ii. 347—Scranton basin, ii. 351—south of Shamokin, ii. 294, 295—Silver Creek, &c., ii. 90—north and south sides of the valley compared, details, ii. 81—Zerbe's Run, ii. 310—west of Zerbe's Gap, ii. 312.
Coal-basins between Alleghany Mountain and Laurel Hill, ii. 495—form of eastern division, ii. 48—in Anthracite region, i. 118—B b and C b, ii. 102—in Bituminous coal region, i. 120—of Head and Big Mountain, ii. 267—scenery from the exterior basins, i. 23.
Coal-bed E, details, ii. 78—lifted by axis D, 86—north of D, tabulated details, ii. 98—at Donaldson and further west, ii. 225—in Eastern Mine Hill, ii. 199—Mill Creek basin, ii. 223—Pinebrook and Lackawanna basin, ii. 352—Sharp Mountain, ii. 23, 187.
Coal-beds south of Carbon Run, ii. 307.
Coal-field west of Chestnut Ridge. ii. 500, 504—between Mill Creek and West Norwegian, ii 141—east of Middle Creek undulations, ii. 179—New Brunswick, ii. 945—undulations of the str., ii. 28.
Coal-fields, ii. 465—American and European, ii. 1015—British, ii. 977—of British Provinces, ii. 942, 954—of the United States, &c., ii. 942.
Coal-formation in the Wyoming and Lackawanna basin, ii. 321.
Coal-measures, ii. 49, 486. 758—in basin, Pottsville anti., ii. 36—in Bear Ridge, details, ii. 269—bituminous, ii. 7—in bituminous coal region, i. 119—Broad Mountain, ii. 7, 225, 226—Buck Ridge and Peaked Mountain, ii. 212—Coal run basin, ii. 299—Coal-run Gap, ii. 292—composition of, ii. 956—Dripping Arch axis, ii. 154—East Buck Mountain, ii. 243—Green Ridge anti. axis, ii. 288—Hazleton coal-basin, ii. 256—iron ores, ii. 736—Lackawanna basin, limits, distribution, ii. 323—Little Schuylkill, ii. 82, 83—lower productive, i. 109—Locust Mountain, ii. 277—Little Mahanoy Mountain, ii. 270—between Mine Hill and Broad Mountain, ii. 201—Mine Hill Valley, ii. 233—Mine Ridge and Mount Carmel, ii. 278—Missouri basin, ii. 966—Smethport, ii. 554—Panther Creek Valley, ii. 67—Red Ridge, ii. 287—Sharp Mountain, ii. 53, 149, 150—Shenandoah Valley, ii. 271—southern basin, ii. 47—Stafford Meadow Valley, ii. 320—Tamaqua, ii. 76—upper or newer, ii. 19—organic remains, i. 109—west of the Catawissa road, ii. 290.
Coal Region, structure, i. 577.
Coal Ridge anti. flexure, ii. 293.
Coal-rocks, chemically derived, ii. 14—mechanica origin, ii. 13—Pennsylvania, ii. 13—vital origin, ii. 14—schutes, ii. 73.
Coal-seams above Carbondale, ii. 331—north of Carbon Run, ii, 307—great extent, ii. 799—Nesquehoning mines, ii. 59—Scranton, ii. 345, 354—Zerbe's Run, ii. 309.
Coal-shales, ii. 19—organic remains, i. 109—newer, i. 20.
Coal strata, limits, ii. 795—nature, ii. 796—Rhume Run, ii. 54—under the conglomerate, ii. 666.
Coalbrook, ii. 383.
Coalbrookdale coal-field, ii. 978.
Coaldale, ii. 29, 30.
Coal Hill, ii. 532.
Coal Mine Run, ii. 64.
Coalmont, ii. 452.
Coal Run, ii. 269, 521—basin, estimate of coals, ii. 301—structure of, ii. 296, 297.
Coal-run Gap, ii. 298—Ridge, ii. 303—anticlinal, ii. 291—Tioga River, ii. 520—Valley, ii. 303.
Coatesville, Aur. limest., i. 214—Pri. sandst., i. 166—Pri. rocks, i. 175, 176—Pri. series, i. 122—Pri. slates, i. 174.
Cobb's Gap, ii. 319—Ser. series, i. 147—Umb. series, i. 145—Vesp. rocks, i. 143.
Cobus Creek, Mat. limest., i. 246—Creek Valley, Aur. limest., i. 246.
Cockle coal, identification, ii. 170.
Cockle's red-ash seam, ii. 432—vein, ii. 153, 154.
Cocolamus Creek, i. 392—Verg. and Cad. rocks, i. 115.
Codorus Creek, i. 185, 193—Aur. limest., i. 222—cleavage, i. 191—mouth of, ii. 680.
Coffee Run, Cad. and Verg. rocks, i. 523.
Coganhouse settlement, ii. 510.
Cogan's Openings, Bedford Forge, iron ore, i. 525.
Colahan's colliery, ii. 117—mine, ii. 126.
Colchester and Hants coal-field, ii. 947.
Cold Spring, altered rocks, i. 206—Vesp. conglomerate, i. 293.
Colebrook, ii. 687.
Colebrookdale township, crystalline limest., i. 201—gneiss, i. 201.
Coleman ore-banks, Safe Harbour, i. 218.
Colerain, coal-measures, ii. 246—forge, i. 500—mill, Aur. limest., i. 501.
Collieries, Silver Creek and Mill Creek, ii. 125—West Norwegian, ii. 147—West Norwegian and Swatara, ii. 168.
Collins's mine, ii. 391.
Colt's coal, ii. 388, 403.
Colt's station, i. 578.
Columbia, Aur. calc. sandst., i. 123—Bridge gneissic rocks, i. 79—mica slate, i. 68—to Chiquesalunga Creek, i. 193—cleavage, i. 221—Pri. rocks, i. 193—Pri. series, i. 122.
Concretionary structure of Verg. str., i. 581.
"Cone-in-Cone" structure, i. 581.
Conemaugh Gap, Chestnut Ridge, Vesp. rocks, i. 143—Laurel Hill, i. 143, 146—river, i. 33—viaduct scenery, i. 34.
Conemaugh, ii. 617—furnace, ii. 660.
Conequenessing Creek, ii. 578.
Conewango Creek, Pri. sandst., i. 166, ii. 556—Falls, ii. 677—Hills, ii. 687—Falls, trap-dykes, i. 49—Bridge, intrusive rocks, i. 190—Chapel limestone quarries, i. 223—ore-bank, i. 219.
Conformable continuous sequence, ii. 777—interrupted sequence, ii. 778.
Conglomerate beds in Verg. str., i. 298—roof, Muddy Branch, ii. 157.
Conglomeritic rocks, McGinnes's Hollow, ii. 205, 206.
Conneaut Creek, i. 578, ii. 559—Lake, i. 39, i. 578—calc. marl, i. 586—town, Cad. sandst., i. 584.
Conecocheague Gap, i. 331—sync. belt. of limest., i. 347—Mountain, i. 331—Cad. rocks, i. 314—iron sandst., i. 338—iron ore, i. 339—Pri. str. i. 203.
Conedogwinit Creek, i. 257—sulphuret of iron, i. 260—Mat. slate, i. 260.
Conestoga, aspect of the Susquehanna River, i. 49—Creek, eastern branch, Aur. limest., i. 218, 221—trap-dyke, i. 221—limestone, i. 185—limestone basins, i. 218—Valley, i. 176.
Connecticut Valley, red sandst., ii. 694.
Connellsville, ii. 500, 502—section, ii. 621.
Connequenessing, ii. 492.
Conoloway Creek, i. 428—fracture in strata, i. 424.
Conoloway Ridge, i. 423.
Conolly's drift, ii. 564.
Connor and Roads' slope, ii. 125.
Conshohocken anti. belt of Pri. rocks, i. 162—beds, Matson's Run, i. 165—Ridge anti., i. 211—trap-dyke, i. 165.
Contact of coal-beds and marine limestones, ii. 804.
Contortions in coal strata, i. 235.
Conularia Trentonensis, ii. 819.
Cornwall mines, Lebanon county, i. 181, 182.
Conyngham's farm, ii. 371.
Conyngham road coal-basins, ii. 253—Valley, anti. ii. 242.
Cook's coal, ii. 454.
Cook's Gap, i. 371, 379, 380—Pheasant Valley, i. 487.
Cool Spring Creek, ii. 563.
Cool Spring furnace, ii. 472.
Cooper coal, ii. 410, 411—Pine Swamp Run, ii. 411.

Cooper's Gap, i. 476—mine, ii. 407.
Cooper or Orchard bed, ii. 408—Point, octahedral iron, i. 187.
Copeland's mill, Mat. black slate, i. 480.
Copper mine, ii. 709.
Copperas mine, near Breinigsville, i. 265—run, i. 84.
Copper ore associated with trap, ii. 687—Cornwall iron-mines, ii. 719—Lake Superior, ii. 748—nickel-mine, ii. 1022—veins, ii. 700.
Copp's Settlement, ii. 568.
Cordaites, ii. 877.
Cornulites flexuosis, ii. 823.
Cornwall iron-mine, trap-dykes, ii. 687.
Cornwall iron-mines, ii. 718—ore-hills, ii. 719.
Correlation of American and British Palæozoic strata, cited, ii. 785.
Coudersport, ii. 487, 546—Umb. series, i. 146—Vesp. rocks, i. 143.
Council Ridge, anti. axis, details, ii. 241.
Courson's Hampden mine, ii. 344.
Cove, anti. axis, i. 381, 382, 387—Cad. black slate, i. 393, 394—Cad. slate, i. 394—Mer. sandst., i. 390.
Cove forge, Mat. slates, i. 505.
Cove Mountain, i. 23, 118, 382, 569—Surg. strata, i. 565—Mono. crest, i. 14—Ponent sandst., i. 364, 327—Surg. ore stratum, 561—Umb. red shale, i. 365—Vesp. rocks, i. 365.
Covington, ii. 483, 524.
Cowanesque, ii. 525—Creek, ii. 485, 486, 487—anti. axis, i. 308—Valley, Ponent red shale, i. 311.
Cowan's Gap, Levant sandst., i. 331—Tuscarora Mountain, i. 320.
Cowanshannock, ii. 486, 586.
Cox's Drift, ii. 644.
Cramley's Hill, i. 360.
Crain's Quarry, Crain's Mill, i. 583.
Cranberry colliery, ii. 260—Creek, ii. 241—coal, ii. 263—Ridge anti., ii. 255—shaft, details, ii. 258—Big coal-seam, ii. 255.
Crane ironworks, ii. 727.
Crawford calc. limest., i. 584—topographical features, i. 576.
Creitz Creek, i. 185—Aur. limest. quarries, i. 222.
Crematopteris, ii. 868.
Cressonville, ii. 433.
Creswell's iron-ore bank, i. 433—ore-bank, i. 425.
Cretaceous deposits, ii. 765—Physical geography, ii. 767.
Crill's mill, ii. 564.
Crooked Creek, ii. 486, 525, 589, 592—Bend, ii. 591—remarkable lake, 312—Plum Creeks, ii. 591.
Crosby coal, Mecke's western tunnel, ii. 208—Sando's colliery, ii. 207—Staunton's tunnel, ii. 209—Staunton's Broad Mountain tunnel, ii. 221—seam, ii. 444.
Cross Creek, ii. 242—coal, ii. 262.
Cross-cut coal, ii. 101—Reinhardt's Run, ii. 78—Tamaqua, ii. 215—vein, ii. 99.
Crossley's iron-ore pits, ii. 706.
Crow Hollow, ii. 420—basin, ii. 31—coal-beds, ii. 131—Mammoth Vein colliery basin, ii. 31—Mammoth coal, ii. 87.
Croyle's mills, ii. 653.
Crum Creek, i. 70—hornblendic gneiss, i. 78.
Crust-waves, ii. 890—movement, close of Mat. period, ii. 784—end of Mat. period, ii, 786—undulations, ii. 1.
Crystal Ridge anti., ii. 254—slope, ii. 258.
Cucumber Run, ii. 665.
Culm, ii. 991.
Cumberland, i. 139—Cad. upper black slate, i. 140—coal-basin, ii. 4—coal-field, ii. 981—furnace, ii. 267—Pri. white sandst., i. 204.
Cumberland Scalent grey marls, magnesian limest., i. 538—Prem. limest., i. 539—Valley, ii. 2—syn. belt, i. 334, ii. 4—19th anti. axis, i. 317—Maryland line, i. 569—iron foss. ore, i. 566—topography south of Bedford, i. 568.
"Curly Back" limest.-beds, i. 499.
Curtis's coal, Sharon, ii. 561.
Curwinsville, ii. 536.
Cuts printed in text, i. xxvi.
Cwmbola, ii. 417—anti. structure, ii. 35—Clarkson coal, ii. 219—Lewis vein, ii. 124—Palmer coal, ii. 125—synclinal axis, ii. 126.
Cyathaphyllum turbinatum, ii. 827.
Cyclopteris, ii. 855.
Cypris Leidyi, ii. 771.
Dado's tunnel, ii. 33, 34, 115.
Dale's Hill, limest.-quarries, hæmatitic ore, i. 460—Sca. limest., i. 438.
Daniell coal, Mecke's western tunnel, ii. 208—Peaked Mountain, ii. 208—Pine Knot colliery, ii. 204—Sando's colliery, ii. 207—Staunton's tunnel, ii. 209—seam, ii. 444.
Daniell seam, Lewis Doherty's colliery, 205.
Danville, arg. limest., i. 537—Bridge, Sca. limest. i. 451—Mer. slate, i. 137—Mer. rocks, thickness, i. 399—section of Montour Ridge, i. 444—Surg. older slate, i. 442—Narrows, Levant white sandst., i. 435, 462—Surg. iron-sandst., i. 436—rocks, i. 132, 133, 134, 436, 437—shales, i. 398—slates, i. 397—upper calc. shales, i. 442—Verg. rocks, i. 439.
Darby Creek, felspathic gneiss, i. 70—porphyritic gneiss, i. 69—third belt of gneiss, i. 73.
"Dark Swamp" bog-ore, i. 280.
Darlington's Corner, serpentine, i. 170.
Dauphin basin, i. 13, ii. 20, 164—structure, ii. 179—coal-measures, ii. 193—Rattling Run, ii. 197—coal-measures, ii. 188—structure, ii. 27—coal str., ii. 37—Big Flats, ii. 198—coal-basin, i. 24, 26, 114, ii. 440—Valley, i. 118.
Davis's ore-bank, i. 479—Hill, i. 513—openings, iron-ore, i. 524.
Dawson, Prof. J. W., cited, ii. 942.
Deal Bank, ii. 491, 570.
Deer Creek, ii. 559, 571—augitic syenite, i. 190.
Deerhole syn. valley, i. 488.
Delavie's quarry, Washington, i. 454.
Delaware Bay, i. 48—county, felspathic syenite, i. 70—gneissic rocks, i. 76, 77—gneissic ridges, i. 94—and Hudson counties, ii. 334—Coal and Canal Company's coal, ii. 331—subdivisions of Main coal-bed, ii. 334.
Delaware to the Lehigh slate cleavage, i. 247—mine, (west), ii. 425—Post-mer. rocks, 279—Pri. sandst. and gneiss, i. 196—River, i. 4—basin, i. 40, 41—closed in 1780, i. 55—anti. flexures, i. 240—Aur. limest., i. 241—Mat. limest., i. 125—Mer. slates, i. 439—scenery, i. 47—scenery near Lehigh, i. 47—tabulated description, i. 43—syn. flexures, i. 240—Valley scenery, i. 37—Water-gap, i. 29—Cad. str., i. 279—northwards to Broadhead's Creek, i. 271, 272—dislocation at, ii. 884—Levant sandst., i. 277—Levant grey sandst., 126, white sandst., 130—Mer. rocks, i. 278—Prem. limest., i. 278—River scenery, i. 47—showing dislocation, ii. 896—slate quarries, i. 247—to Strasburg, Mat. slate, i. 260—Surg. rocks, 131, 132, 277—Wind Gap, i. 283.
Delaware Valley scenery, i. 32.
Delthyris congesta, ii. 828—cuspidata, ii. 829—granulifera, ii. 828—lynx, ii. 820—medialis, ii. 828—macropleura, ii. 825.
Dendrerpeton acadianum, ii. 944.
Depositions and disturbances of Aur. period, ii. 781—Cad. series, ii. 791—Levant period, ii. 788—Mat. period, ii. 783—Mer. series, ii. 790—Pon. series, ii. 793—Postmer. series, ii. 791—Prem. series, ii. 790—Pri. period, ii. 779—Sca. series, ii. 789—Surg. series, ii. 789—Umb. series, ii. 794—Verg. series, ii. 792—Vesp. series, ii. 793.
Derbyshire coal-field, ii. 980.
Description of Eocene, ii. 769—fossil coal-plants, ii. 847.
Desor, Professor E., on Pleistocene, ii. 775.
Detailed description of bituminous coal region, ii. 507.
Devonian equivalents, ii. 750.
Diagonal lamination in Verg. flags, i. 296—Verg. stra., i. 581.
Diagram of European formations, ii. 742.
Dial Knob, ii. 326.
Diamond coals, ii. 92, 109, 130, 340—bed, ii. 128, 136—basin, undulations of the coal, ii. 352—identification, ii. 170.
Diamond colliery, ii. 419—basin mines, ii. 352—drift, ii. 341, 353—mines, Swetland Meadows, ii. 352—general section, ii. 352—shaft No. 2, ii. 353—coal H, ii. 354—rock, i. 123—to Paoli, i. 175—Pri. rocks, i. 173—Pri. sandst., i. 174.
Diamond seam, ii. 426—Pinebrook, ii. 352—seams, ii. 419.
Dickey's Mountain, i. 326, 419—Levant sandst., i. 324—Mer. sandst., i. 424—Surg. and Sea. rocks, i. 415.
Dick's Ridge axes, i. 361—anti. axes, i. 360, 317—Cad. grey sandst, i. 356—Cad. and Verg. rocks, i. 360—Sca. and Prem. limest., i. 350—Mer. sandst., i. 353.
Diehl's drift, ii. 420.
Dill coal, ii. 148.
Dill's and Ewing's mill, ii. 587.
Dillsburg, ii. 683, 689—limest., i. 204—Prim. str., i. 203.
Diluvial scratches, Wyoming Valley, ii. 941.
Diluvium, drift, or glacial deposit, i. 37.
Diplostegium, ii. 869.
Dip of Mesozoic red sandst., ii. 761.
Dip mine, ii. 331.
Dip of Pri. str., i. 190, 191.
Direction and dip of the cleavage-planes, i. 248.
Dirt fault, ii. 415.
Dislocated flexure, ii. 237.
Dismal Swamp, ii. 847—Virginia, ii. 845.
Distribution of coal-plants, Lesquereux, ii. 837.
District township, Pri. white sandst., i. 201.
Disturbances at end of Aur. period, ii. 783.
Dividing Mountain, i. 26, 318—Levant sandst., i. 332—Mat. slate, i. 322.
Dobson coal, ii. 128.
Dodd's cannel coal, ii. 596—farm coals, ii. 336.
Dodson's Big coal outcrop, ii. 411—school-house, ii. 385—anti., ii. 390—Lane, ii. 387.
Dogwood Run, Aur. limest., i. 258—limest., i. 204.
Dolbin and Rogers' colliery, ii. 432.
Dolph's Mill, Vesp. rocks, ii. 361.
Dolomitic rock, i. 210.
Donaldson, ii. 154, 438—basin coal-seams, ii. 180, 181, 232—Big vein, ii. 156—Black Heath coal, ii. 216—coal-beds, ii. 225—Ten-feet coal, ii. 156—coal, Middle Creek, ii. 178—coals in gap of Big Lick Mountain, ii. 182—syn. valley, details, ii. 46.
Donolley's mill, ii. 602.
Dorsey and Green's ore-banks, details, i. 516.
Dougherty's mine. ii. 443.
Downingtown Aur. limest. quarries, i. 214—Valley, Pri. slates, i. 158—Pri. rocks, i. 151—Pri. sandst., i. 166.
Doylestown turnpike, gneissic rocks, i. 81.
Drainage lake, i. 41—Mexican Gulf or Ohio River, i. 42.
Drake's Narrows, Lev. sandst. mountain, i. 478—Run, ii. 659—Run, Seral conglomerate, ii. 25.
Dreck Creek coal-basin, ii. 251—Valley, coal-basin, ii. 240.
Drift, i. 59—in coal-bed, ii. 1010—formation, Pennsylvania, i. 37—later local, 775—in Northampton, Lehigh, Delaware, &c., i. 38—in north-west district, i. 585—stratum, ii. 774—in western division, fourth district, i. 312—in Western Pennsylvania, i. 38.
"Drifts" or "levels," ii. 56.
Driftwood branch, ii. 482, 484, 538.
Dripping Arch, anti. axis, ii. 154, 155—and Phœnix mines, anti. axis, origin, range, details, ii. 42.
Dromotherium sylvestre, ii. 697.
Drumore, Aur. limest., i. 176.
Drury's Run, ii. 483.
Dry Hollow, ii. 50—Ridge, red-ash coals, ii. 71.
Dry Ridge, Cad. and Verg. rocks, i. 573—composition, 564.
Dry Run anti. axis, i. 315.
Dry Valley, i. 408, 403—Sca. limest., i. 401—syn. structure, i. 409.
Dublin Gap, mineral spring, i. 260—Hollow, i. 335—Hollow anti. axis, i. 317.
Dull's saw-mill, Mountain Creek, i. 205.
Dumont, M., on Belgium, i. 900.
Dunbar Creek, ii. 501, 612—section, ii. 610.
Dunbar mill, ii. 612.
Duncannon, Pon. sandst., i. 364.
Duncan's Island, Main Juniata, i. 5—Pon. red sandst., i. 363—trap-dyke, i. 366—Point anti., i. 187.
Dundas collieries, ii. 427, 428, 437—Black Valley coal, ii. 168.
Dunfermline coal-field, ii. 985.
Dunmore coals, ii. 338—Hill coals, ii. 343—Ridge anti. axis, ii. 343.
Dunning's Creek, i. 561, 564—exposition of strata, i. 566—Gap limest. quarries, i. 562—of Surg. str., i. 560—of Surg. rocks, i. 567.
Dunning's Mountain, i. 15, 117—exposition of str., i. 557—vertical dips, i. 507.
Durham Cave, i. 99, 236.
Durham Creek, ii. 681—gneiss, i. 100—limestone, i. 234—Pri. sandst., i. 196—unconformity of dip, i. 100.
Durham Hills, Aur. limest., i. 100—structure of gneiss, i. 99.
Durham iron mine, ii. 715—and Newcastle coal-field, ii. 980—ridge of gneiss, i. 234—Pri. series, i. 123.
Durham river scenery, i. 47.
Dutch Corner, dips of str., i. 562—Cove, i. 561—Surg. ore shales, i. 557—Surg. shale and marl formations, i. 560—syn. flexure, i. 568.
Dutchman's Run, ii. 513.
Dutch settlements, ii. 510.
Dutotsville, Surg. red shales, i. 272.
Dyctiopteris, ii. 861.
Dyke of trap-rock, i. 182—Sorrel Horse Tavern, i. 221.
Dynamic value of coal, ii. 1018.
Eagle colliery, ii. 420—Creek, Big Hazleton coal-bed, ii. 255—furnace, cliffs of Cad. rocks, i. 552—Gap Sca. limest., i. 546—Sca. and Prem. limest., i. 546.
Eagle Hill colliery, details of the outcrops of the coals, ii. 128, 129.
Earthquake undulations concerned in production of coal strata, ii. 807.
East Boston basin, coal-beds, ii. 269.
East branch of red clay anti. axis of gneiss, i. 227—Swatara south-dipping str., ii. 167—East Caln Church Aur. limest., i. 214—Council Ridge anti. axis, details, ii. 241—Creek, ii. 522.
Eastern Carb. district, anthracite basins, ii. 20.
Eastern Midde coal-basins, i. 118—coal-field, i. 147, ii. 7—Umb. red shale, ii. 12.
Eastern Mine Hill, central anti. axis, details, ii. 199—anti. axis, ii. 199—anticlinal, ii. 200.
Eastern Pennsylvania, subdivisions of the district, ii. 5—Shade Mountain, Lev. rocks, i. 367.
Eastern-Middle anthracite coal-field, ii. 239.
East Goshen Friends' meeting-house, i. 168—liberty, ii. 622—mine, ii. 65—of north branch, i. 143—Norwegian, ii. 424, 141, 142—basin H h, ii. 39—Creek Valley, mining details, ii. 85—Peach Mountain coal, ii. 34—synonym of the coal, ii. 223.
Easton to Monroe (see section A), i. 98—road, i. 95—turnpike toll-gate, ii. 389.
East Tennessee oolitic limestone, i. 238.
East Valley Creek, Pri. rocks, i. 173.
Eckl's tunnel, ii. 439—Eckman's Run, limest. belt, i. 214—Edgehill, ii. 122.
Economic considerations respecting coal, ii. 997.
Edgehill, gneiss rocks, i. 80—limest. basin, i. 159—Pri. str., i. 80—Pri. rocks, i. 152, 160—Pri. series, i. 122—Pri. str., i. 77—Ridge, i. 151—gnessic rocks, i. 161.
Edgehill, thickness of Pri. rocks, i. 155—village, exposures of Pri. rocks, i. 156.
Edmiston Bank, pipe ore, i. 500.
Edward furnace, Blue Ridge, i. 369.
Edward's and Morgan's tunnel, Black Valley coal, ii. 217.
Egg-conglomerate, ii. 198—Buck Ridge, ii. 210, 211—Rausch Creek, ii. 165—Swatara Falls axis, ii. 177.
Egg Hill, i. 493—composition, i. 483
Elephant, ii. 773.
Elephas primogenius, ii. 774.
Elevation of main water-shed, i. 2—South Mountains, i. 91—theories of strata, ii. 905.
Elizabeth copper-mine, ii. 707.
Elk, i. 120—county, ii. 487—Creek, i. 578, ii. 508—Verg. str., i. 582—limest. quarry, fossils, i. 493—

Narrows, i. 484—Lick coal, ii. 488, 493, 494—Lick Creek, section, ii. 651.
Elk Mountain, ii. 484, 520, 540, 541.
Elliotsburg, Sca. and Prem. limest. Ridge, i. 349—Syn. knob, i. 361.
Ellisburg, Pon. str., i. 142.
Emlenton, ii. 575.
Emmerick's Mill, conglomerate, i. 575.
Emmettsburg, ii. 691.
Emmons on Mesozoic of North Carolina, ii. 696—researches, ii. 694.
Emporium, ii. 486, 541.
English's Run, ii. 518.
Entelodon, ii. 771.
Eutrican's Coal, ii. 455.
Eocene formations, ii. 768—physical geography, ii. 770—strata, ii. 769.
Epidote, ii. 687, 688.
Epler's Tavern, marble quarry, i. 491.
Epsom salts, manufactured, i. 171.
Equus, ii. 773.
Equisetites, ii. 850.
Erect petrified trees, Carbondale, ii. 846.
Erie County, topographical features, i. 576—extension canal, i. 578.
Erosion of anti. belts, ii. 921—anti. ridges, ii. 922—horizontal str., ii. 917—monoclinal belts, ii. 919—mono. valleys, ii. 921—surface between the Delaware and Lehigh, i. 249—syn. belts, ii. 924, 927—terraced ridges, ii. 931—unsymmetrical anti. ridges, ii. 940.
Errors corrected in note, ii. 416.
Escarpment of Verg. flags, i. 286, 287.
Eshalman's Run, limest. trough, i. 218.
Estheria, ii. 827.
Etna Ironworks, i. 505.
Etting Coal, Bear Gap, ii. 192.
Euphrata, limest. quarry, i. 222.
European formations, ii. 742.
Evans' Ore-bank, i. 217.
Evaporative power of coals, ii. 1002.
Evit's Creek, Cad. and Verg. rocks, i. 569—mountain, i. 15, 117—anti. axis, structure, i. 509.
Ewing's Mill, ii. 587.
Exceptions to a prevailing law of flexures, ii. 894.
Explanation of origin of coal, ii. 806.
Exposures of strata, second anti. belt of Fifth District, i. 114.
Extent of certain coal-beds, ii. 799.
Eyster Gap, ii. 309.
Fairchild's, ii. 379.
Fairfield, ii. 684, 691—Aur. limest., i. 224.
Fairmount, gneissic rocks, i. 67, 79—quarries of gneiss, i. 70.
Fairplay, ii. 458.
Fairview, Cad. and Verg. rocks, i. 535, 578—inn, i. 11—pictorial sketch, i. 32.
Fall Brook, conglomerate, ii. 330, 333.
Fall Creek, ii. 513—section, i. 512—Towanda Basin, i. 145—Umb. series, i. 145.
Fallowfield township, calc. limest., i. 584.
Falls Road, Big Seam, ii. 351.
Fallston Vein, ii. 582.
Fan-like structure of the Alps, ii. 991.
Fannettsburg, i. 331—Matinal slate, i. 322.
Farrandsville, ii. 528—conglomerate, i. 551—furnace, i. 550.
Fathomless Spring, i. 494.
Fault near Birmingham, i. 504—anticlinal D. ii. 87—Canoe Mountain, i. 504—in coal-beds, ii. 236—at Newkirk tunnel, ii. 99—in the Coal-measures, ii. 27—between first and second mountains, i. 482—in flexures, ii. 898—Friends Cove, i. 508—Goslin Run Gap, i. 513—in the Lackawanna coal-basin, ii. 334—at Little Juniata Gap, i. 502, 514—Mahoopeny's quarries, i. 550—in middle zone of gneiss, i. 86—Path Valley, details, i. 319—Peach Mountain Basin, ii. 94—Pri. str., Chique's Ridge, i. 195—and slips of the coal str., ii. 234—between the Sca. limest. and Surg. slates, i. 526—Stone Mountain, i. 513—in Stone Mountain, details, i. 477—in Tucker's Slope, ii. 104—in undulated str., ii. 895.
Faust Coal, ii. 221—Bettinger's mines, ii. 177—Chillis' Hollow, ii. 140—Oliver's colliery, ii. 127—Salem colliery, ii. 175.
Faust's Tavern, coal-beds, ii. 269.
Fayette, Umb. rocks, ii. 11.
Fayetteville, limestone, i. 205.
Fegeley's ore-beds, i. 88.
Felis intrepidus, ii. 773.
Fellow's drift-mine, ii. 344—mine, ii. 341—outcrops of coals, ii. 352.
Felspathic gneiss, i. 76—northern belt, i. 79—southern zone, i. 70.
Fenestella, ii. 827.
Ferguson's Valley, Cad. black slate, i. 425—Surg. foss. ore, i. 432—Surg. rocks, i. 412.
Fern of Pon. str., ii. 830—undetermined affinity, ii. 868.
Ferns, ii. 853.
Ferriferous coal-bed, ii. 496—limestone, ii. 488, 490, 491, 495, 568, 580, 582, 585, 592.
Ferris, Samuel, coal-beds, ii. 336.
Ferryhouse, Springmill, i. 76.
Fifeshire coal-field, ii. 985.
Fifth Basin, ii. 583—in bituminous coal region, details, i. 120—and anti. axis, ii. 486—traced, ii. 487—in the anthracite coal region, i. 119—west to Genesee river, ii. 525.
Fifth District, first anti. belt of, i. 114—first syn. belt of, i. 114—fourth syn. belt, i 115—second anti. belt, i. 114—second syn. belt, i. 114—third anti. belt, i. 115—third syn. belt, i. 115.
Fifth and sixth basins, ii. 546.
Fifty-feet Coal Vein, ii. 51, 60.
Filices, ii. 853.
Filices or fern leaves, ii. 878.
Fillmore colliery, ii. 261—conglomerate, ii. 241.
Finley's Gap, character of the str., i. 495.
Fio forge, Stillman's Swamp, i. 564.
Fireclay Hill, i. 286.
Fire Vein, on West-West Branch, ii. 159.
First basin north-west of the Alleghany Mountain, ii. 480—bituminous coal region, i. 120—traced south to Cambria County, ii. 527—west to Pine Creek, ii. 507, 508, 510.
First belt in the anthracite region, i. 118—of the sixth district, i. 434.
First coal-basin, ii. 7.
First sub-basin, base of Chestnut Ridge, ii. 603—south of Loyalhanna, ii. 604.
First and second basins, Somerset and Fayette, ii. 650
First subdivision of third basin, ii. 500.
First Twin Coals, details, ii. 79.
Fish-egg lime, i. 215.
Fisher's Basin, ii. 43, 154, 157—the coals of, ii. 178, 437.
Fishing Creek, i. 116—anti. belt, i. 453, 454—scenery of, i. 49—Ridge, i. 446—Sca. limest., i. 438, 451—section of Montour Ridge, i. 441—Valley, Cad. and Verg. str., i. 361—Pon. red sandst., i. 364.
Fitton, Dr, on structure of Wealdon, ii. 900.
Fitzgerald's coal, ii. 398—school-house, ii. 388.
Fitzimmon's coal, ii. 128, 419.
"Five-feet Seam," ii. 341.
Five-mile board, Charles Pott coal, ii. 219.
Flagstone group of gneissic rocks, spring of pure well-aerated water, i. 72.
Fleming's Gap, i. 496—dip of the str., i. 488.
Flexure and elevation, theory of, ii. 911—folded, ii. 889, 890—in groups, ii. 892—how related to each other, ii. 887—normal, ii. 889—in the chain of the South Mountains, i. 94—of strata, ii. 891—symmetrical, ii. 888—at Wind-gap and Lehigh Water-gap compared, i. 287.
Flintstone Creek, Sca. and Prem. limest., i. 509, 510.
Flintstone Ridge, i. 383—Cad. and Verg. rocks, i, 392—Prem. chert, i. 388.
Flowerytield slope, ii. 424—tunnel, ii. 424.
Fluor spar, i. 479.
Fogerty's colliery, Black-mine coal, ii. 170—slope, ii. 433.
Foglesville, ii. 724.
Foliation, ii. 904.
Foot-marks, ii. 694—in coal str., ii. 833—prove progress in animal life, ii. 832—of reptiles, ii. 831.
Forest county, ii. 487.
Forest lands and coal lands compared, ii. 1017.
Forest Improvement Company's mines, ii. 434.
Forestville colliery, ii. 431.
Forge Creek, ii. 400.
Forge Ridge, i. 370, 377, 408—Surg. rocks, i. 378—forking of basin, west of Willow Grove, i. 160.
Formative actions producing Palæozoic str., ii. 811.
Fort Laramie, ii. 772—Littleton, i. 423—sulphate of barytes, i. 414—Mifflin, winds, i. 57.
Fossil fishes, ii. 695—flora of Great Britain cited, ii. 803.
Fossiliferous iron-ore, ii. 729—limestone, Pittsburg, ii. 631—ore str., Hollidaysburg, ii. 730.
Fossil plants of the coal str., ii. 835—remains of Virginia Mesozoic coal, ii. 764.
Fossils, animal, of coal str., ii. 833—of the Atlantic Pleistocene, ii. 773—of the Aur. strata, ii. 817—of the Cad. str., ii. 826—of the coal-formation, ii. 810—of Eocene, ii. 769—of Lev. str., ii. 821—of Mat. shale, ii. 818, 820—of Mer. str., ii. 825, 826—of Mesozoic, of Virginia, ii. 696—Miocene, ii. 771—North Carolina oolitic basin, ii. 764—Pon. str., ii. 830—Prem. limest., ii. 824, 825—Pri. str., ii. 815—Sca. str., ii. 824—surg. str., ii. 822—Verg. str., ii. 829—Vesp. and Umb. str., ii. 830.
Foster, Mr, cited, ii. 964.
Foster's coal-bank, ii. 458.
Four-feet coal, Wilkesbarre, ii. 322.
Fourth basin and anti. axis, ii. 485—in bituminous coal region, i. 120—traced into Jefferson county, ii. 540—west to Pine Creek, ii. 524.
Fourth belt in the anthracite coal region, i. 118.
Fourth district, anti. valleys, i. 307—composition, structure, &c., i. 36—north-eastern division, i. 305—Swatara to the Susquehanna, i. 293—syn. mountains, i. 307—western division, structure, i. 307.
Fourth and fifth basins, ii. 592, 596.
Fourth Mountain coal-bed, ii. 198.
Fourth or north-eastern district, i. 294.
Fox Hill, cocktail grits, i. 285—limest. and sandst. ridge, i. 272—Prem. rocks, i. 272.
Frampton's, ii. 587.
Franklin, ii. 489, 556, 562—colliery, ii. 432—county, belts of slate and limest., i. 261, 262—Mat. rocks, i. 112—Surg. rocks, i. 328.
Frankstown, branch of Juniata river, details, i. 50—Cad. rocks, i. 139, 140—Cad. and Verg. rocks, i. 540—Cove, i. 553, 556—Knob, from the top of Blue Knob, i. 557—Mer. rocks, i. 137, 138—Mer. slates and sandst., i. 539—Prem. limest., i. 136—Prem. limest., thickness,, i. 539—Sca. limest., i. 136—Valley, pictorial sketch of, i. 30.
Frantz and Company, mines, ii. 424.
Frea's Corner, Pri. rocks, i. 163.
Fredensburg, i. 200—Pri. slate, i. 198.
Frederick county, Maryland slate quarries, i. 188, 189.
Frederick Neal's ore-banks, i. 217.
Fredericktown, ii. 645.
Freeburg, Sca. marls, i. 405.
Freemansburg, i. 96.
Freeport, i. 120, ii. 488—coal, ii. 492, 592—lower, ii. 579, 582—upper, ii. 493, 579, 582.
Freeport coals, ii. 572, 577, 584, 630—group, ii. 580, 581—limest. and coal, ii. 485, 492, 579, 587—sandst., ii. 492—section, ii. 595.
French buhr-stone, i. 529.
French Creek, i. 577—Cad. sandst., i. 584—iron ore, i. 585.
French's tunnel, ii. 409—anticlinal, ii. 408.
French Village, Coal-measures, ii. 251.
Frey's Run, limest., i. 233.
Friedensburg, conglomeritic sandst., i. 291—iron mine, ii. 716—slate valley, i. 102.
Friend's Cove, i. 117—anti. axes, i. 469, 507—structure, i. 9.
Frozen Run, ii. 516.
Fruits, fossil, ii. 875.
Fruitstown, Verg. rocks, i. 453.
Fucoides, ii. 842, 848—bilobatus, ii. 822—found by Brongniart in coal str., ii. 843.
Fuel, qualities of, ii. 1000, 1006.
Fuller's Creek, slope mine, ii. 355.
Fulling Mill, Sca. limest., i. 387.
Fulton county, Prem. limest., i. 136.
Fulton's Gap, Bald Eagle Ridge, i. 498.
Fungineæ, ii. 847.
Furgusson's mill, Cad. olive shales, dip, i. 551.
Furnaces, ii. 578—Great Western, ii. 578.
Furnace Hills, i. 164, 165—Sandy Creek, ii. 562—vein at the West Branch, ii. 171.
Galena limest., ii. 784.
Gallagher's Ridge, i. 362.
Galloway's Gap, belt of Sca. limest., i. 413, 418.
Gangways in Panther Creek tunnels, ii. 74.
Gaps in anti. ridges, ii. 933—Nippenose Valley, i. 489.
Gardiner's Creek, ii. 367, 369.
Gardner coal-bed, ii. 225.
Gate coal-beds, ii. 36, 173—Salem colliery, ii. 175.
Gate Vein, Bettinger's mines, ii. 177.
Gate Range, the coal str. of, ii. 185.
Gate Ridge, ii. 175—anti. axis, ii. 36, 40—below Llewellyn, ii. 167—at Pottsville, ii. 152.
Gatesburg Bank, pipe ore, i. 500.
Gatiss's mine, ii. 513.
Gaylord's land, ii. 411—mine, ii. 407, 408—section, ii. 412.
Gebhart's Run, ii. 308.
General description of bituminous coal-basins, ii. 477.
General section of Pittston Coal-measures, ii. 361.
General structure, ii. 323.
General summary, British coal-fields, ii. 987.
General Wayne's farm, belt of serpentine, i. 168.
General vertical section of bituminous coal str., ii. 474, 477.
Genesee Basin of Lake Ontario, i. 42—group, ii. 755—river drainage, i. 35—Verg. rocks, i. 140, 141—Verg. shales, thickness, i. 297.
Geneva, ii. 614.
Geographical distribution of Cad. rocks, i. 356—of cretaceous str., ii. 765—of metamorphic azoic str., ii. 746, 747—of Miocene, ii. 770—Umbral, ii. 468—of Verg. rocks, i. 356—Vespertine, ii. 467.
Geographical range of the rocks of the South Mountains, i. 91.
Geological areas, ii. 743.
Geological age of red sandstone, ii. 692.
Geological sections, i. xxvi.
Geology of the United States, ii. 741.
George's Creek, ii. 503, 648—section, ii. 614.
George's Valley, i. 482—anti. arg. limest. i., 494.
Georgetown, ii. 489, 559.
Gerard, anti., i. 582.
Gerhart's Run, anti. flexure, ii. 281—exposures of coal, ii. 289.
Germantown, axis in Surg. rocks, i. 315—Prem. and Mer. rocks, i. 347—Surg. rocks, i. 339—syn. tongues of limest., i. 348—turnpike, limest. quarries, i. 213.
German Valley, i. 368—Sca. marls and limest., i. 414—Sca. limest., i. 419—Surg. and Sca. rocks, i. 413.
Gettysburg, ii. 689—railroad, i. 206, ii. 691.
Gibson's mill, axis, i. 317.
Gin Coal, ii. 218.
Girard Tunnel, Ser. conglomerate, ii. 269.
Glacial deposit, i. 37.
Glade Run, ii. 486.
Gladding's Run, Cad. and Verg. rocks, i. 574—rocks, &c., i. 572—Pon. and Vesp. rocks, i. 575—Vesp. conglomerate, i. 575.
Glass, its manufacture, i. 304.
Glen Carbon colliery, ii. 446—tunnel coals, ii. 211.
Glendower colliery, ii. 446.
Glen Rock village, Pri. str., i. 192.
Glover's Valley, anti., i. 337.
Glyptocrinus decadactylus, ii. 821.
Gnathadon cuneatus, ii. 774.
Gneiss, belt north of Mooretown and Attleborough, Pri. sandst., i. 80.
Gneiss district north of Chester Valley, i. 85.

Gneiss, division of middle zone of, i. 83—faults in the middle zone of, i. 86.
Gneiss and granite belt, Susquehanna river, i. 190.
Gneiss hills in Lehigh and Berks, i. 97—west of the Monokesy, i. 102—iron ores of the gneiss, i. 87—in the Lehigh hill, i. 233—limits of middle gneissic belt, i. 77—southern belt, boundaries, i. 76—northern belt, i. 77, 78—of the three belts of the southern district, i. 76—two principal ranges, i. 84—in magnesian limestone, i. 230—near Marlborough meeting-house, i. 230—middle belt on the Brandywine, i. 82—middle zone, i. 83—narrow ranges and local outcrops west of the Brandywine, i. 81—northern belt on the Brandywine, i. 82—northern branch of French Creek, i. 85—in New Jersey, i. 233—Chadd's Ford, i. 81—from Edge Hill to Morrisville, i. 80—east of the Schuylkill, i. 197, 198—in hills east of Reading, i. 199—north of Chester County valley, i. 85—near Pricetown, i. 198—varieties near the toll-gate west of Morgan's Corner, i. 78—southern zone, boundaries, i. 67—southern belt west of the Brandywine Creek, i. 81—strike near Easton, i. 245—structure of the upper or northern belt, i. 74—subdivisions and details of northern belt on the Schuylkill, i. 75.
Gneissic rocks, ii. 744—boundaries of, i. 83—west of Rocky Mountains, ii. 748.
Gneissic str., ii. 700—str., three districts, i. 66.
Gneissic and Azoic rocks, ii. 746.
Gneissic belts near Chestnut Hill, i. 96—hills, calamine, near i. 101—or Hypozoic rocks, i. 59, 60, 64—region of the Schuylkill, i. 78—or Hypozoic rocks, i. 111—ridges south of the Lehigh, i. 96—rocks, i. 92—Berks county, i. 94—Chestnut Hill, i. 93, 94—Coventry village, i. 83—east of Unionville, i. 77—French Creek Valley, i. 83—Ist belt, i. 68—Ist zone, boundaries, i. 66—Mine Ridge, i. 83—north-west branch of the Octorara, i. 83—of Schuylkill Valley, i. 67—second or middle belt, i. 71—south-east of Sterner's Inn, i. 198—near Spring mill (*see* section), i. 164, 165—South Mountains, i. 112—of the South Mountains, boundaries, i. 91—northern belt of, i. 73—undulations in the Philadelphia belt, i. 76—Welsh Mountain, i. 83—west of the Schuylkill, i. 83.
Godfrey's Ridge, limest. quarry, ii. 282—Mer. and Post-mer. rocks, i. 284—Prem. limest., i. 283—south-west of Stroudsburg, i. 284.
Goetz Mine, ii. 722.
Gold of California, ii. 748.
Gold Mine Gap, coal-beds, ii. 195.
Goniatites interruptus, ii. 829.
Good Spring Creek, i. 118, ii. 47—near Donaldson, ii. 163—Gap, grey-ash coal-seams, ii. 164—Valley, ii. 179, 180—gap, details of the coals, ii. 182.
Gorgas iron-ore bank, i. 266.
Goslin Run Gap, fault, Surg. ore sandst., i. 513, 515—Surg. ore, i. 515.
Goss's coal, ii. 532—limest. quarries, i. 226.
Gottman's limest. quarry north-west of Pennsborough, i. 542.
Gould coal-bed, ii. 409, 411.
Gould and Shank's mine, ii. 411.
Gradations in coal, ii. 995—in the coal str., ii. 797—in flexures, ii. 892—in volatile matter in coal, ii. 808, 809.
Gradual increase westward in thickness of limest., ii. 798.
Græffenburg Springs, Pri. rocks, i. 205.
Grampian Hills, ii. 482.
Grand Tunnel, ii. 409.
Granite dykes, i. 170—north of Knauertown, i. 232—in Pleasant Valley, i. 227—near West Grove meeting-house, i. 228.
Granite veins in gneissic rocks, i. 69—in northern belt of gneiss on Schuylkill, i. 75.
Granitic dykes, ii. 698, 706.
Granitic gneiss in Pleasant Valley, i. 228.
Graptolithus pristis, ii. 820.
Grape Knob, i. 405.
Grassy Island coal, ii. 334—details, 336.
Grassy Run, ii. 615.
Grave Mountain, alterations of the str., i. 531.
Gray's Ferry, gneissic rocks, i. 68.
Great Appalachian coal-field, i. 32.
Great Aughwick Valley, i. 385, 411, 426—Cad. rocks, i. 427—structure, composition, i. 427—limest. belt., i. 419—Mer. sandst., i. 423—Pon. red sandst., i. 429.
Great Bed, ii. 421—at Carbondale, ii. 332.
Great Bend, the, i. 48.
Great Limest., ii. 628—coal stratum, ii. 53.
Great Surface Mine, ii. 52.
Great Western Furnace, ii. 577.
Green Briar Valley, i. 421, 422, 425—limest. ridge, i. 417.
Greencastle, Aur. limest., i. 259—Mat. slates, i. 259.
Green county, ii. 507—group, ii. 503—Upper Barren coal-rocks, ii. 20.
Greenfield, ii. 642.
Green Mountain, ii. 243—east coal-basin of, ii. 243—details, ii. 264.
Green Park coal, anti. axis, ii. 39—of Mill Creek, ii. 137.
Green Ridge, altered rocks, i. 206—anticlinal, ii. 278—Pri. rocks, i. 207—Gap, details, syn. troughs, ii. 284—Mine Company's coal openings, ii. 286—Pri. rocks, i. 203, 207—the State line, i. 204.
Green Run, Cad. lower black slates, i. 552.
Green's Run, exposure of foss. chert, i. 545.
Greentree Run, gneissic rocks, dip, i. 79.
Greensburg, ii. 492, 577.
Greenstone, ii. 699.
Greenville, ii. 560—Cad. sandst., i. 584.
Green village iron-ore bank, i. 268.
Greenwood Breaker Basin, ii. 30—colliery, Reed imp. lands, ii. 447—furnace, i. 479—Surg. shales, i. 515—tunnel, coal-beds, ii. 67—coal E, ii. 79 — coal F, ii. 68—details of the coals, ii. 83, 214, 215.
Gresh's, Mr, i. 200.
Grey-ash coals at Donaldson, ii. 231—Silver Creek, ii. 228 — Tamaqua, ii. 76 — West Branch and Wolf Creek, ii. 231 — west of Donaldson, ii. 164 — Little Schuylkill, ii. 227—Mill Creek, ii. 229—in Panther Creek Tunnel, No. 9, ii. 75.
Grey Vein, Middle Creek, ii. 156.
Grier coal, details, ii. 100, 414—Tuscarora, ii. 216—details, ii. 102,
Griffin farm, coal-beds and strata, ii. 349—mine, ii. 350—ravine, ii. 342—ravine, tabulated details of the coals, ii. 350—west of Scranton, details of the coals, ii. 350.
Griffith farm, coals, ii. 341.
Griffith, Mr, on structure of Ireland, ii. 900,
Grindstone Hill, i. 259.
Griscom anti., ii. 44—details, ii. 161—mines, ii. 172.
Groom's quarry, i. 153.
Groover's school-house anticlinal, ii. 378.
Groundhog Valley, i. 521—iron ore, i. 529—Umb. series, i. 145.
Grove's fulling-mill, ii. 682.
Grove's Licks, Mat. slates, i. 486.
Gruff's tavern, Surg. calc. ore shales, i. 455.
Guiterman's coal, ii. 109, 119—colliery, ii. 418.
Gulf Creek, i. 162—outcrop of serpentine, i. 168—mills, structure of the Aur. limest. belt, i. 211.
Gulf of Mexico, i. 52—St Lawrence, i. 52.
Guth mine, ii. 723.
Gulick's Gap, ii. 397.
Guysborough coal-field, ii. 950.
Gypsum, amount quarried, ii. 948.
Hacket's Gap, " nests " of iron ore, i. 293.
Haddon township, mica slate, i. 77
Hain's inn, limest. trough, i. 164.
Haine's pit, ii. 724.
Haldeman's mansion, condition of the Pri. str., i. 194.
Half Fall Rapids, i. 51—Mountain, i. 51, 114—anti. axis, i. 316—Cad. shales, i. 139—Mer. sandst., i. 352—thickness of Cad. str., i. 356—Verg. str., i. 356—composition, i. 358.
Half-Moon Run, limest. and sandst., i. 501—Valley, i. 502.
Hall's limestone quarries, east of Williamsport, i. 542.
Hall and Rawle's old ore-bank, i. 479.
Hamersville, calc. marl, i. 586.
Hamilton, ii. 900—group, ii. 755.
Hamilton's old opening, ii. 455.
Hampton mines shaft, tabulated details, ii. 350.
Hancock, belts of limest., i. 419—coals, ii. 136—south of Carey's shaft, ii. 134—vein, ii. 32.
Hannah Furnace, Surg. rocks, i. 552.
Hanover Furnace, Surg. cellular ore, i. 432—junction, cleavage, i. 191—ore-bank, i. 479.
Harbour Mountain, i. 528, ii. 449—iron ore, i. 529.
Hardy's ore-bank, i. 377.
Hare's Valley, iron ore, i. 411, 412—Mer. sandst., i. 519—Pon. str., i. 427—Sca. and Prem. limest., i. 417—topography, i. 521.
Harmony, ii. 580—Verg. shales, i. 306.
Harper's slope, ii. 425.
Harris's banks, pipe ore, i. 499.
Harrisburg, Aur. limest., i. 257—close foldings in Mat. slate, i. 246—Aur. limest., i. 251—Susquehanna River, i. 49.
Harrol's coal-bank, ii. 605.
Hartleyton Mountain, i. 457.
Hartman Tract, Daniell Coal, ii. 211—coal str., ii. 212.
Hartslog Valley, i. 50—Surg. foss. ore, i. 516—Sca. limest., i. 518.
Harvey's Creek, i. 116—mine, ii. 410—tunnel, ii. 409.
Hasbruck's quarry, ii. 785.
Haven's Lewis Slope Coal, ii. 138, 139.
Havener's Big Coal in Pinkerton's tunnel, ii. 126—mine, ii. 126.
Havre-de-Grace, gneiss, i. 190.
Hawkshaw, description of erect fossil trees, ii. 805.
Hayden, Dr, discoveries by, ii. 764—account of Miocene basin, ii. 772.
Hazleton and Beaver Meadow plateau, i. 147.
Hazleton coal-basin, ii. 241, 252—North Branch, ii. 255—slope No. 1, Big Coal, ii. 257, 258—Great Coal-bed, ii. 259, 260.
Hazle Creek, conglomerate, ii. 23—Big Coal, ii. 252.
Head Mountain, i. 118—pebbles of conglom., ii. 22, 23—anti. axis, ii. 267.
Hearod's Tavern, ii. 526.
Heckscher New Mines, red-ash colliery, ii. 154, 155.
Heckscherville, ii. 445—colliery, ii. 444.
Heilner's Kantner Drift, ii. 172—Slope, Black Valley coal, ii. 217—Primrose coal, ii. 217—Wolf Creek, Black Heath coal, ii. 216.
Heil's Colliery, ii. 439.
Heister's Valley, i. 374.
Hellertown Road, conglom., i. 102—spurs of gneiss, i. 97.
Hell-kitchen Ravine, ii. 263.
Helm Iron-ore bank, i. 268.
Hematitic iron-ore, i. 7—Pickering Creek Basin, i. 87.
Hemlock Creek, i. 462, ii. 562—iron ore and sandst., i. 445, 446—section of Montour Ridge, i. 441.
Hemlock Run, ii. 544.
Henderson's, ii. 128, 562.
Henry Clay iron furnace, Pri. sandst., i. 194.
Hendrickson's Gap, Lev. rocks, i. 566.
Hereford township, Pri. white sandst., i. 201.
Hertzoff's Gap, Vesp. rock, i. 143.
Hertzoff Hollow, ii. 321, 406—iron ores, ii. 407—Ser. series, i. 147—Umb. series, i. 145.
Hervey's Lake, i. 453.
Hickory Creek, ii. 558.
Hick's Quarry, i. 153.
Hicksville Mer. sandst., i. 547.
Hiefner's Bank iron ores, i. 269.
Highlands in New Jersey, gneissic rocks, i. 93.
Highspire village, i. 49.
Hill's Boring, Mine Hill, ii. 205.
Hill iron-ore bank, i. 268.
Hill Valley, Sca. and Pre-mer. limest., i. 417—Surg. rocks, iron ore, i. 412.
Hill's Tunnel, Daniell Coal, ii. 205.
Hipparion, ii. 773.
Hoffman Coal, Bear Gap, ii. 192—mines, ii. 723.
Hogback, ii. 392, 399, 401—Ridge, composition, structure, i. 281, 282.
Hogeland's Run, ii. 481, 510, 511.
Hokendaqua Furnaces, ii. 726.
Hole Creek, Mat. newer slates, i. 255.
Hole Mountain, i. 26—Lev. grey sandst., i. 255—Mat. slate, i. 255.
Hole Valley, anticlinal, i. 290.
Holiday's ore-bank, i. 479.
Hollenback's coal, 369.
Hollenback's mill, ii. 398.
Hollidaysburg, i. 116, 140—Cad. shales, i. 139—formations to its south-west, i. 557, 559—Turnpike ridges of strata, i. 566—Ver. flags, i. 541.
Holliday's Run, black slate, i. 425.
Hollow stumps of trees, ii. 847.
Holly Furnace, i. 204, 267.
Holman and Company's Slope, Oak Hill Coal, ii. 171.
Holm's Creek, altered rocks, i. 206.
Holmes Coal, ii. 419.
Holoptychius, ii. 522, 525.
Homalonotus, ii. 829.
Homberger's, exposure of coals, ii. 288.
Hominy Ridge, Pon. red sandst., i. 363.
Hoof's Inn, gneiss, i. 197.
Hoope's Sawmill, serpentine outcrop, i. 169.
Hoover's Coal, ii. 387.
Hope Furnace, belt of limest., i. 417—iron ore, i. 413—Mer. sandst. ridge, i. 421.
Hope village, i. 7.
Hopewell Coal Company, ii. 462—diggings, iron ore, i. 524—furnace ore-pits, ii. 707—iron mines, i. 85.
Hopkins on the axes of the Wealdon, ii. 900.
Horizons of continuity and discontinuity, ii. 777.
Horizontal strata locally eroded, ii. 928.
Hornblendic gneiss, i. 72, 168.
Horrelstown, Aur. limest., i. 478.
Horse Valley, i. 331—position, structure, composition, i. 344.
Horton's, ii. 543.
Hough's Run, Pri. white sandst., i. 189.
Howard Furnace, block ore, i. 537—Cad. olive slates, dip, i. 552—Gap, ore, slate hills, i. 545.
Howey's coal-opening, i. 263.
Hudson River, slate group, ii. 752.
Hugh's Camp Run, Verg. and Pon. rocks, i. 573.
Huling's Sawmill, Cad. black slate, i. 425.
Hull's Coal, near Scranton, ii. 337.
Hummelstown, Aur. limest., i. 251.
Hunter's Mill, Cad. and Verg. strata, i. 429.
Hunter's Mill, Surg. red shale, i. 455—Valley, ii. 11—Umb. red shale, i. 365—Vesp. conglom., i. 365.
Huntingdon, i. 117—furnace sawmill, Pri. and Aur. rocks, i. 501.
Huntingdon County, Mat. black slate, i. 260—oolitic limestone, i. 238.
Huntingdon, pictorial view from Warrior Ridge, i. 13—the Verg. strata of, i. 580—turnpike, Pri. strata, i. 159—Valley, i. 50—Verg. rocks, i. 140, 141.
Hurst's Salt Well, ii. 605.
Husband's Mill, ii. 658.
Hyænodon, ii. 771.
Hyde Park, ii. 355—Bluff, ii. 342.
Hydraulic lime above Siegfried's Bridge, i. 249.
Hydrogenous coals, ii. 995.
Hydrographic areas, i. 3.
Hydrography of Pennsylvania,—tabulated details, i. 39, 40.
Hymenophyllites, ii. 863.
Hypozoic and Azoic rocks, ii. 744—gneiss, along the Brandywine, i. 64, 158.
Ice cave near Perryville, i. 479.
Ickesburg, fourth anti. axis in the Cad. rocks, i. 314—third anti. axis in Surg. shales, i. 314—Mer. sandst., i. 351—Pre-mer. limest., i. 346, 347—Surg. slates and marls, Sca. limest., i. 337.
Igneous rocks and minerals, ii. 698—in southern zone of gneiss, i. 69.
Illinois and Indiana coal-field, ii. 959.
Illustrations, i. xxv.
Indian Creek, ii. 498, 663—Harper's quarry, i. 255—section, ii. 664.
Industry, ii. 582.
Ingram's Coal, ii. 650.
Inman's, ii. 386—coal, ii. 396.

Instances of great longitudinal faults, ii. 898.
Instantur, ii. 551.
Introduction, i. i.
Introduction of coal as fuel, ii. 1012.
Intrusion of melted matter, ii. 905, 906.
Iowa coal-field, ii. 964.
Irish coal-fields, ii. 985, 986.
Iron and coal at M'Ginnis's Hollow, ii. 205, 206.
Iron and copperas mine, west of Trexlerstown borings, details, i. 265.
Iron (fossiliferous) ore, i. 413—outcrop near Bedford, i. 566—Little Cove, i. 416—Germantown, i. 339—near Hartleyton, i. 459—of the Surg. ore shales, Montour Ridge, i. 447—Pfout's Valley, i. 337—in Racoon Valley, i. 337—Slenderdale Ridge, i. 375—in Surg. rocks, Ferguson's Valley, i. 412.
Iron foundry axes, ii. 362.
Iron furnaces, ii. 666—at Astonville, ii. 516.
Iron mines, ii. 708, 724—Cornwall, ii. 719.
Iron ore, i. 204, 205, 223, ii. 17, 19, 514, 516, 517, 518, 519, 527, 537, 585, 654, 655, 657, 712, 715, 720, 725, 726—three miles above Allentown, i. 264—analysed, ii. 721—argillaceous, in the coal strata, ii. 14—Aur. and Mat. strata, ii. 722—Buchanan's ore, north of Oakland Hotel, i. 217—bank one mile north of Marble Hall, i. 216—Milliton's, i. 216—Otto's, i. 216—Thomas Widdart's, i. 216—Woodman's, i. 216—of the Nittany Valley, i. 499—south-west of Hanover, i. 222—five miles west of north from Bethlehem, i. 263—(bird's eye), i. 171—in Blacklog Mountain, i. 371—at Black Spring Gap, ii. 195—near Blain's, Shade Gap, i. 394—south-west of Bloomfield, i. 360—Broad-Top, ii. 464—Broad-Top region, i. 529—Buck Ridge, i. 339—in Buffalo Valley, i. 459—Cacoosing, i. 251—of the Cadent lower black slate, i. 432—Cadent older black slate, i. 527—in Cadent slate at Little Cove, i. 262—in Cad. slate at Shade Gap, i. 394—of Cad. and Verg. series, ii. 732—south of Canton Corners, tabular details, i. 309—Carlisle iron-works, i. 266, 267—westward from Carlisle, i. 267—east of Chatham's Run, i. 551—Chester Furnace, i. 433—Chestnut Hill, near Columbia, i. 182, 183—Chestnut Hill Mine, base of the Pri. slate, i. 183—(chromiferous), in serpentine rocks, i. 170—of Coal-measures analysed, ii. 739—of the Coal-measures of the Scranton coal-field, ii. 308—coal strata, ii. 735—coal, Thick Mountain, ii. 181—near Cold Spring Branch, i. 258—west of Coatesville, i. 217—Conecocheaque Mountain, i. 339—west of the Conestoga, i. 217, 218—at Danville, i. 443—south-west of Yellow Springs, i. 89—east of Elliotsburg, i. 361—Emaus, i. 264—Emmettsburg, ii. 691—below Fitzimmon's coal, Zachariah's Run, ii. 128—Forge Ridge, i. 377—on the slopes of Fishing Creek, i. 448—(fossiliferous), i. 374—George Fisher's, i. 216—of the gneiss, i. 87, ii. 714—of the strata in Great Augbwick Valley, i. 431—Great Western Furnace, ii. 578—at Hacket's Gap, i. 293—Hare Valley, i. 522—between Hecktown and Butzville, i. 263—Hertzoff's Hollow, ii. 407—Hitner's Banks, i. 216—Holland's Bank, north-west of Howellville, i. 217—Hollidaysburg, i. 566—Howard Furnace, i. 545—near Howellville, i. 216—Hughes and Jones, i. 216—Ickesburg, i. 357—Indian Creek, i. 255—north-east of Jonestown, i. 254—Juniata Furnace, i. 358—Kishacoquillas Valley, i. 479—Kittatinny Valley, i. 263—Kittatinny, yield of, ii. 727—at Klinger's Gap, ii. 190—Kressler's Mine, i. 268—south of Kutztown, i. 266—Mr Lail's land, i. 526—Lehigh to the Schuylkill, details, i. 263—west of Lewistown, i. 410—Lewistown Valley, i. 400—Liberty Valley, i. 336—and limest. west of Loudon, i. 269—Little Cove, i. 429—Little Eagle Tavern, i. 90—south-east of Littleton, i. 394—Little Trough Creek, i. 529—near Mark's Mill, ii. 690—of the Mat. slates, ii. 728—the Mat. slate along the fault in Path Valley, i. 322—near Meadville, i. 584—Mer. sandst., i. 353—metamorphic rocks, ii. 713—Millerstown, i. 380—in Berk's County, i. 181—south-west from Montalto, i. 258—in Montour Ridge, details, i. 449—of Montour's Ridge, i. 450, ii. 730—Montour's Ridge, proportion of soft foss. ore in, i. 450—total quantity in, i. 448, 449, 450—Moreton's Run, i. 361—Mount Braddock, ii. 625—Nanticoke, ii. 399—Oak Grove, i. 362—Furnace, i. 361—near Parnell's Knob, i. 262—Pecquea, i. 217, 218—Perry County, i. 351—Pfout's Valley, i. 336—Pigeon Hills, i. 223—pit, Baptist meeting-house, i. 216—south of Bethel Hill, i. 216—Polecat Valley, i. 362—north-west of Prater's Ridge, i. 426—Pre-meridian and Meridian, ii. 731—Pri. series, ii. 718—Pri. strata, i. 181, 201—north of Reading, i. 266—mine, near Reading Turnpike, i. 251—Red Fall Creek, ii. 513—Rehrersburg Road, i. 254—Rice and Loy's Banks, i. 361—stratum at Roseville, Mill Creek, &c., i. 311—Saint Thomas, i. 269—near Valley Forge Dam, i. 217—Sandy Ridge, i. 352—near Scranton, ii. 357—connected with Sca. limest., i. 526—east of the Schuylkill, i. 216—west of the Schuylkill, i. 216—near Shippensburgh, i. 268—Sinking Spring, i. 251—Spring Mill, i. 216—Stone Valley, i. 516—near Stouchtown, i. 251—Stumpstown, i. 254—near Stuart's Mill, i. 379—near Sugar Creek, i. 585—Sugar Valley, i. 491—Supplee and Hampton, i. 216—of Surg. series, ii. 729—Titaniferous, i. 171—near Tomstown, i. 258—near trap-rock, ii. 690—Tussey Mountain, i. 523—of Umbral, ii. 511, 529—series, ii. 734—strata, ii. 471—in Uwchlan township, i. 90—(Verg.) west of Larry's Creek, i. 550—in Verg. north branch of Susquehanna, i. 309—Walnut Bottom Road, i. 267—Walter's Bank, i. 433—Warrior Ridge, i. 518—near Waynesburg, i. 258—Well's Creek, ii. 656—West Grove Meeting-house, i. 227—Wyoming Basin, ii. 404.
Iron, product of, ii. 1021.
Iron sandstone in Lewistown Valley, i. 397—Montour Ridge, i. 442.
Ironstone Creek, limit of gneiss on the south, i. 98.
Iron trade, ii. 1020.
Irregular coal, ii. 605.
Island Mine, ii. 716.
Isotelas gigas, ii. 819.
Isothermal lines, i. 52.
Jack's Creek, Cad. older black slate, i. 400—Gap, Surg. shales and marls, i. 398—Mountain, i. 21, 114, 364, 403—anticlinal, i. 115, 116, 397, 521—west of Brown's Gap, i. 477—anti. axis of main spur, i. 463—anti. axis, Pon. red sandst., i. 430—Pon. strata, i. 427—debris of Mat. sandstone, i. 480—Gap, foss. ore, i. 410—Surg. slates, i. 397—iron ore, i. 412—Juniata, anti. axis, i. 464—Lev. white sandst., 458, 515—mono. crest, i. 15—ore sandst., i. 410—pass, i. 29—Pri. rocks in, i. 203, 207—range, i. 457—structural features, i. 477—Surg. rocks, i. 132, 133, 134—Surg. iron ore, i. 522—Surg. str., ii. 133, 134.
Jack's Narrows, i. 50—Surg. str., ii. 132.
Jackson Seam, ii. 413.
Jackson's, William, limest. quarry, i. 227.
Jacksonville, silicious str., i. 496.
Jacob's Creek, ii. 501, 502, 503, 604, 615—Old Furnace, ii. 663—second sub-basin, ii. 608—section, ii. 607.
Jacob's (G. W.), ore-bank, i. 217, 377.
Jamie's Ridge, ii. 305—anticlinal, ii. 287—Gap, mine-drifts, ii. 285, 286.
Jamieson's Old Mine, ii. 394.
Jaquish's, ii. 407.
Jeanesville, ii. 244—Big Coal, ii. 250—Colliery, ii. 245—coal in middle basin, ii. 249—South Slope Mine, ii. 248.
Jeddo Lands, coals, ii. 261, 262.
Jeddo, structure of coal-basin, ii. 242.
Jefferson Ore-bank, ii. 726.
Jemmy's Ridge, ii. 279, 280.
Jenkin and Company's colliery, ii. 425.
Jenkins's Mill, ii. 565—syn. axis, i. 350.
"Jenny Jump," New Jersey, i. 7.
Jenning's Run, Maryland, Cad., Verg., and Pon. rocks, i. 574, 575.
Jersey Shore, Cad. and Verg. rocks, i. 550—Sca. limest., i. 539—Surg. olive shales, i. 543—Surg. ore shales, i. 537.
Jessup, ii. 333—Lackawanna Railroad Company's mines, ii. 335.
Jock Vein, or Coal J, ii. 79.
Joggings, remarkable section, ii. 945.
John Beck's bank, pipe ore, 499.
John's Coal, ii. 109—Adam's tunnel, ii. 205—colliery, Great White-ash Coal, ii. 87—Great Coal-bed, ii. 200—New Slope, Mill Creek, ii. 132.
Johnson's Creek, ii. 522—Gap, Lev. grey sandst., i. 487—salt-works, ii. 598.
Johnsonsburg, ii. 552.
Johnstown Basin, ii. 496, 497.
Johnstown, section at, ii. 653.
Jones and Coles' colliery, mining operations, details, ii. 103—and Mason's slope colliery, ii. 146—Mine, ii. 687—Mine, Morgantown, i. 178—Mine, sketch of, i. 190—and Spencer's slope, Peach Mountain Coal, ii. 172—Mine, near Yellow Springs, i. 89—and Beaver iron-ore mines, near Centreville, i. 217—T. R. on beyrichia and leperditia, ii. 834—tunnel, Black Valley Coal, ii. 217.
Jordan Creek, iron ores, i. 264—knob, i. 262, 334, 336, 344.
Jugular Coal, ii. 202—bed, ii. 232—McGinnis's colliery, &c., ii. 217—McGinnis's Hollow, ii. 205, 206—Mecke's western tunnel, ii. 208—Mine Hill Valley, ii. 205—Sando's colliery, ii. 207—colliery, ii. 444—vein, details, ii. 274.
Juliana Furnace, Surg. rocks, i. 552.
Juniata, above Bell's forge, i. 554—County, Surg. rocks, i. 373—anti. of valley of Juniata County, i. 373—furnace, 8th anti., i. 315—anti. axes in Prem. limest., i. 348—Mer. sandst., i. 352—Gap, Lev. grey sandst., i. 127—series, i. 127, 129, 130—sandstones, i. 500—red sandst., i. 129—white sandst., i. 130—Great Bend, i. 115—Mer. sandst., i. 522—River basin, i. 42—Frankstown branch, i. 50, 559—Sca. and Prem. limest., i. 348—scenery, i. 31, 32—Surg. and Sca. rocks, i. 115—township, Pon. red sandst., i. 363—Valley, i. 50.
Jura chain of Switzerland, ii. 901.
Jurassic coal-formation, ii. 763—age of Mesozoic, ii. 696.
Kansas, supposed Permian, ii. 759.
Kantnor Coal, ii. 43, 158, 159, 172—Peach Mountain Basin, ii. 43—Coal, Primrose Hill, ii. 153, 154, 155.
Karthaus, i. 120, ii. 483, 535.
Kear's Mammoth Colliery, ii. 443—slope, Oak Hill, ii. 172—vein, ii. 427.
Kellysburg, ii. 589.
Kelly's Hollow, Big Coal, ii. 203, 442.
Kennedy's Valley, i. 335, 343, 344—Surg. rocks, i. 344.
Kennet Square Basin, Pri. and Aur. rocks, i. 229—gneiss rocks, i. 81—limest. basin, i. 81, 226.
Kensington Furnace, ii. 575.
Kentucky Upper and Lower Coal-measures, ii. 962—western coal-field, ii. 961—iron ores, ii. 962.
Kenzua, ii. 488, 556—Creek, ii. 489, 541, 553, 554, 555.
Kerr and Albright, ii. 723.
Kesler's mineral spring, gneiss rocks, i. 197.
"Kettle," the, i. 21—Creek, i. 49, ii. 482, 483, 526—Mountain, i. 118, 303—mono. crest, i. 14.
Keyser's Creek, ii. 343, 344—south-dipping strata, ii. 350.
Kier's colliery, ii. 431.
Kimberton Aur. limest., i. 231.
Kimber's Run, ii. 463.
Kimmel's tavern, coal-rocks, ii. 165.
Kindling coal, ii. 316.
King, Dr, discoverer of footprints, ii. 833.
King's tavern, Aur. limest., i. 223.
Kinsel's, ii. 587.
Kinter's Mill, ii. 587.
Kishacoquillas Creek, i. 406—anti. and syn., i. 407, 408—Prem. limest. hills, i. 402—sources of Middle Branch, i. 476—Gap, Lev. grey sandstone, i. 127—Lev. series, i. 127, 129, 130.
Kishacoquillas Valley, i. 9, 116—anti., i. 462, 478—Aur. Mag. limest., i. 124—dip of str., i. 486—Levant red sandst., i. 473—Mat. series, i. 125—Pictorial sketch, i. 10, 13—topographical description, i. 475.
Kiskiminetas, i. 120, ii. 484, 598—section of, ii. 599.
Kitchen Creek, ii. 50—Gap, ii. 50, 54.
Kittauning, ii. 486, 488—coal-bed, ii. 491, 496, 570, 582, 592—section, ii. 593—Mountain, Lev. rocks, variations of type in the line of outcrop, i. 276, 277.
Kittatinny, Mahoning, and Sharp mountains, pictorial sketch, i. 9.
Kittatinny Mountain, i. 14, 47, 113, 114, 333—dislocated at Delaware Water-gap, ii. 884—evidences of erosion, i. 249—Gaps, i. 28—Mat. newer slate, i. 240—Mer. rocks, i. 137—length, i. 8—Pre-mer. limest., i. 136—roofing-slate, i. 247—Sca. rocks, i. 135—spur, i. 334—Surg. iron sandst., i. 329—Susquehanna, Lev. rocks, i. 328—syn. and anti. knobs, i. 270, 271—Cad. str., i. 356.
Kittatinny Ridge, i. 246.
Kittatinny Valley, i. 114, 115, 118—Aur. limest., i. 251—Aur. rocks, i. 117—Aur. and Mat. rocks, i. 112—boundaries, i. 237—Cad. rocks, i. 138, 139—cleavage, i. 237—dimensions, i. 237—geological composition, i. 237—constitution, i. 112—structure, i. 240—Mat. shales, i. 125—Mat. slate, i. 253, 254—north-eastern division, i. 241—ores, ii. 723, 725—organic remains, i. 237—scenery, i. 7, 49—structural features, i. 237—topography, i. 237—type of the formations, i. 238.
Kitzmiller, Stees, and Co.'s colliery, ii. 440.
Kleckner's Gap, Aur. limest., i. 492—dip of sandst., i. 487.
Klinesville red slate, i. 249.
Klinger's Gap, ii. 182—anti. Q, ii. 164—coal str., mode of mining, ii. 189—Ser. series, i. 147.
Klopperdale, i. 374.
Knabb's mill, boundary of slate and gneiss, i. 199—Knauertown, Aur. limest. i. 232—iron mines, ii. 709—iron and copper veins, ii. 706.
Knickerbocker Vein, West Branch, ii. 170.
Knight's quarry, i. 153.
Knob Mountain, Pon. rocks, sandst., i. 452.
Knoop and Stiver's bed, ii. 401.
Knowle's Gap, i. 288.
Knoxville, ii. 525—Verg., Pon., and Vesp. rocks, i. 311, 312—Verg. rocks and limestone, i. 312.
Koker's bed, ii. 401.
Kreb's Knob section, ii. 643.
Kreemer's Coal, ii. 403.
Kreidersville, outcrop of Aur. limest., i. 246.
Krupp's Coal, ii. 401.
Kugler Vein, ii. 196.
Kunkle Tract, coal-beds, ii. 256.
Kurtz's Valley, i. 384—anti. axis, i. 373, 378—Cad. and Verg. rocks, i. 392—Pre-mer. chert, i. 388—ridge, i. 393.
Lackawanna Coal-basin, i. 294—form and interior features, ii. 318—coal-field, i. 15, ii. 3—Iron and Coal Company's lands, ii. 357—at Pittston, i. 48—Pon. and Vesp. str., i. 306—and Susquehanna Coal-basin, ii. 6—Valley scenery, i. 31—trough-like structure, ii. 327.
Lackawaxen, Pon. rocks, i. 299—structure of the region, i. 303.
Lacustrine tracts, i. 38—water-shed, i. 40.
Lafayette, ii. 490, 555.
Lake basins, i. 41—drainage, i. 40.
Lake Erie, i. 32, 37—region, Cad. and Verg. str., i. 578—slope, i. 42, 577—streams of north-western slope, i. 52.
Lakes of Central New York, i. 38—north, north-east, and north-west of Central Pennsylvania, i. 38—in Erie and Crawford counties, i. 39—in the Fifth District i. 39—in Pennsylvania, distribution, i. 37—and ponds, general law, i. 38.
Lamar Bank, pipe ore, i. 499.
Lambert's mill, ii. 656.
Lambertsville temperature, i. 56.
Lamborn's Bank, iron ore, i. 500.
Lamna, ii. 769.
Lanarkshire coal-field, ii. 983.
Lancashire and Yorkshire coal-field, ii. 980.
Lancaster Coal Company, ii. 455—city, i. 222—county, Pri. rocks, i. 60—limest. and red shale, ii. 2—Main Serpentine Belt, i. 171—temperature, i. 56—and York counties, limest. valley of, i. 111.

Lance's Grand Tunnel Mine, ii. 410.
Landisburg, Lev. sandst., i. 334—Mer. sandst., i. 353—mono. belt of limest., i. 350—mountain-knobs, i. 314—Sca. and Pre-mer. limest., i. 349—to Sherman's Creek, syn., i. 350—Surg. rocks, i. 342.
Landmesser's coal and tunnel, ii. 395.
Lane's tunnel, ii. 393.
Larkin's estate, outcrops of coal, ii. 263.
Larry's Creek, ii. 510, 511—bog ore, i. 280—iron ore, i. 541—ore-bearing stratum, i. 454—Cad. and Verg. rocks, i. 550.
Larry's Hill, i. 286.
La Salle coal-field, ii. 964.
Latschaw Mine, details, i. 89.
Laughlintown, ii. 662.
Laurel Hill, i. 3, 32, 33, 120, 143, ii. 471, 492, 493, 494—and Chesnut Ridge, ii. 498—Creek section, ii. 657—colliery, ii. 256—coal strata, ii. 257—Umb. series, i. 146.
Laurel Run, i. 330, 514, ii. 323, 370, 376—anti., ii. 334—Sca. and Pre-mer. limest., i. 386.
Laurish's Mine, ii. 724.
Lawrenceburg, ii. 574.
Lawrence Grove colliery, ii. 419.
Laurenceville, Verg. shales, i. 311.
Lawrentian clay, ii. 775—lakes, i. 52—metamorphic belt, ii. 747.
Laws of structure, &c., ii. 238.
Lawton Coal, ii. 139—Oliver's colliery, ii. 127.
Lawton's mines, Jugular Coal, ii. 217—old colliery, &c., ii. 232—Gap tunnel, ii. 202.
Lead, Galena, in Buffalo Valley, i. 460.
Lear Bed, ii. 458.
Lee's Coal, ii. 378—Creek, ii. 392—Mine, Nanticoke, ii. 399.
Leechburg, ii. 597.
Leggett's Gap, ii. 324.
Lehigh, i. 118, 119, ii. 3—Aur. limest., i. 232—Creek, Aur. limest., i. 101—basins, ii. 21—coal-basins, ii. 12—Company, ii. 75—modes for conveying coals to market, ii. 71—Hills, gneissic rocks, details, i. 96—Pri. rocks, northern flank, i. 98—Pri. sandst. and gneiss, i. 195—subdivisions of gneiss, i. 97—and Little Schuylkill Coal Company, ii. 47—district, ii. 26—Mer. rocks, i. 278—metamorphic rocks, Gneiss Hills, i. 8, 97—mountains, cleavage fissures, i. 244, 245—oolitic limest., i. 238—Post-mer. rocks, i. 279—Pon. rocks, i. 300—river, Pon., Verg., and Cad. rocks, i. 289—Pon. str., i. 141—slate quarries, i. 249—Summit coal-mine, ii. 26—Tamaqua, ii. 221—table-land, Pon. rocks, i. 299—Summit mines, i. 25—Verg. rocks, i. 140, 141—Vesp. conglomerate, i. 301—Water-gap, i. 7, 29, 489—dip, i. 288—Mat. slate, i. 273—Lev. grey sandst., i. 127—white sandst., i. 130—Surg. rocks, i. 132, ii. 133, 134.
Lehighton anti., i. 289—Cad. shales, i. 285, 286.
Leidy's researches, ii. 695.
Leightner's land, Surg. red shale, i. 514.
Leighton iron ore-mine, ii. 707.
Lelar Coal in Sando's colliery, ii. 207.
Lemon's Coal, ii. 619.
Lemon Hill, gneissic rocks, dip, i. 79—and Miller's mines, ii. 652.
Leperditia alta, ii. 824—arctica, ii. 824—Pennsylvanica, ii. 823—Bathica, ii. 824—by T. R. Jones, ii. 834.
Lepidodendron, ii. 829, 873, 874, 875—primævis, ii. 828.
Lepidophyllum, ii. 875, 876.
Lepidostrobus, ii. 876.
Leptæna alternata, ii. 818—depressa, ii. 823—incrassata, ii. 817—patenta, ii. 823—seracea, ii. 818.
Leptarchus primus, ii. 773.
Leptauchenia, ii. 771.
Leptochærus, ii. 771.
Lerdoms quarry, i. 153.
Lesquereux, catalogue of fossil plants, ii. 878—deductions cited, ii. 835, 836.
Lesquereux's description of fossil-plants, ii. 847—remarks on distribution of coal-plants, ii. 837, 838, 839, 840.
Leuder Creek, ii. 390.
Levant grey sandst., i. 105—Delaware Water-gap, i. 126—Jack's Mountain, thickness, i. 472.
Levant period, ii. 749—physical geography of, ii. 788.
Levant red sandst., character and thickness, i, 105—Jack's Mountain, i. 473—Kishacoquillas Gap, i. 129—Nittany Valley, i. 498.
Levant rocks, i. 113—Blue Ridge, i. 369—from Delaware Water-gap to Broadhead's Creek, i. 271—Kittatinny Mountain, i. 271—Franklin County, i. 262—north of Lehigh Water-gap, i. 273—Maryland line, i. 567—Milesburg, i. 547—head of Scotoh Valley, i. 555—Shade Mountain, i. 368—Tyrone Gap, i. 553.
Levant sandst., i. 116, 335—Bean's Cove, i. 509—around Blacklog Valley, i. 370—south-east of Blacklog Valley, i. 371—Buffalo Valley, i. 483—Dunning's Mountain, i. 557—in Kishacoquillas Valley, i. 478—Susquehanna Gap, i. 276—Tussey's Mountain, west of Pine Ridge, i. 514.
Levant series, ii. 753—strata, thickness of, i. 126, 131—white sandst. fossils, i. 105—Delaware Water-gap, i. 130, 283—Tussey's Mountain, &c., i. 515—near Jersey Shore, i. 543—Lehigh and Delaware region, i. 473—syn. mountain, i. 482.
Levy and Patton's Mine, ii. 408.
Lewis Coal, ii. 129, 130, 145—local, ii. 111, 112—east side of Mill Creek, ii. 219—colliery, ii. 135—Singley's Farm, ii. 137—slope, Branchdale Colliery, ii. 176.
Lewis Colliery, ii. 428—and Gate coals, ii. 140—and Howell's Colliery, ii. 353—and Howell's Slope, ii. 344—ore-bank, i. 90—ore-bank near Yellow Springs, details, i. 87—red-ash colliery, ii. 423—seam, ii. 423, 426—and Spohn coals, anti., ii. 40.
Lewistown, Cad. lower black slate, i. 138—Mer. sandst., i. 137, 420, 422—Prem. limest., i. 136—Sca. grey marl, i. 398—Sca. limest., i. 398—Sca. rocks, i. 135—Surg. rocks, i. 134—Surg. and Sca. rocks, i. 413—Mer. sandst., i. 137—syn. belt of Mer. sandst., i. 417—Valley, i. 11—Valley, anti. axis, i. 396—anti. and syn. axes, i. 408—boundaries, anti. axes, i. 396—topographical features of strata, i. 17, 401.
Lewistown to Maryland, i. 411—to Waynesburg, syn. axes, i. 420.
Lewis's Tunnel, ii. 158.
Liberty Valley, i. 114, 330—syn. belts, i. 338—Lev. sandst., i. 314.
Lichtenwalder's ore-pit, ii. 725.
Lick Mountain, coal strata, ii. 193—Run, ii. 470, 481, 528—anticlinals, ii. 35—coal, ii. 118, 121—collieries, ii. 85—Peach Mountain Basin, ii. 93—Peach Mountain Coal, ii. 114—Palmer Coal, ii. 218—Valley, ii. 120.
Licking Creek, i. 384—Valley, i. 377—syn. trough, Surg. rocks, i. 376.
Lignite basin, ii. 771.
Ligonier, ii. 662—Valley, i. 120, ii. 483, 497.
Lime Creek collieries, ii. 85.
Limekilns, Cox Reuben, i. 163.
Lime Ridge, near Bedford, i. 562.
Limestones, i, 61, ii. 360, 506, 548, 565, 648—basin of Montgomery and Chester, i. 159—bed, ii. 505—beds near Lewisburg, i. 459—boulders, valley of North Branch, i. 310—Brownsville, 646—Great, ii. 649—north of Chester Valley, i. 232—near Newcastle, ii. 576—pebbles, i. 252, 253—Pittsburg, ii. 634, 635—quarries, i. 98, 99—north-west of Bernville, i. 252—Delaware canal, i. 241—dip, i. 228, 229—Doe Run village, i. 231—east from Emaus, i. 235—from Embreville to Doe Run village, i. 230—south of the Great Valley, i. 225—opposite Harman's, i. 451—east of Hellertown, i. 235—south of Hellertown, i. 235—Hoopes, i. 226—at Irish Creek, i. 252—near Joel Bailey's, i. 228—above Jonestown, i. 255—south of Kutztown, i. 266—near Sacoming Creek, i. 250—west of Lehigh Gap, i. 288—south of middle secondary red sandst., details, i. 224—north-east of Mifflinsburg, i. 457—near Monroe, i. 234—north of Muncy Hills, i. 542—Nickle's, i. 226—Northkill, i. 252—south-east of Orwigsburg, i. 291—near Petersburg, i. 223—near Pennsborough, i. 542—above Reading, i. 252—west of Springtown, i. 235—south branch of the Saucon, i. 235—north branch of the Susquehanna, in Verg. strata, i. 309—above Swatara Bridge, i. 255—Uhlersville, i. 233—Upper Saucon church, i. 235—Wolf's Rocks, i. 291—Upper Saucon township, i. 235
Limestone Ridge, Cad. and Verg. rocks, i. 358—south-west of the Juniata, Cad. and Verg. rocks, i. 393—Mer. sandst. and chert, i. 389—Sca. limest., i. 438—south of Dry Valley, i. 409—Sca. and Prem. limest., i. 386.
Limestone Run, ii. 542, 543.
Limestone Sewickley Creek, ii. 638—troughs and local basins, i. 217—Umb., ii. 472—Conemaugh, ii. 473.
Limestone in Vespertine sandstones, ii. 538.
Limits of Appalachian coal-field, ii. 955—strata, ii. 795.
Limits of Illinois coal-basin, ii. 960—of Western Kentucky coal-field, ii. 961.
Lindley and Hutton, ii. 803—Prof., ii. 842.
Lindner's Gap, Coal-measures, ii. 268.
Line Mountain, i. 21—mono. crest, i. 15.
Line of outcrop, Carbondale, ii. 333.
Lingula, ii. 833—cuneata, ii. 822—curta, ii. 818—oblonga, ii. 828—prima, ii. 815—quadrata, ii. 820.
Liun's Mill, i. 331, 347.
Lion Coal, ii. 140.
Lisburn, ii. 682—red shale at Bryson's, i. 258.
Litiz, dip of limestone, i. 222.
Little Alleghany Mountains, i. 575—River, i. 556.
Little Aughwick Creek, i. 423—Valley, Cad. and Verg. rocks, i. 393.
Little Bear Creek, anti. valley, ii. 5—anti., ii. 6.
Little Beaver Creek, limestone, i. 219.
Little Black Creek Basin, Coal-measures, ii. 262—details of coals, ii. 243.
Little Buffalo Creek, i. 348.
Little Conoloway Creek, Surg. strata, i. 414.
Little Cove, Cad. and Verg. rocks, i. 429—Mer. sandst., i. 424—Mountain, i. 262, 420—Mer. sandst. in syn. belt, i. 424—Lev., Surg., and Mat. strata, i. 327—Sca. and Prem. limestone, i. 419—Surg. and Sca. rocks, i. 415—syn. Cad. black slate, i. 429—syn. trough, i. 327—Valley, form of strata, i. 262.
Little Diamond Coal, ii. 38, 142, 153, 154—slope, ii. 172—West Branch, &c., ii. 218—Wolf Creek, ii. 173.
Little Elk Creek, serpentine, i. 169, 170.
Little Gap, flexures, i. 288.
Little Grey-ash Vein, Swatara Creek, ii. 156—coal, Fisher's Basin, ii. 178.
Little Juniata Gap, fault, i. 514.
Little Lick axis, ii. 173—anti. ii. 177—Mountain, ii. 439—anti. axis, ii. 46, 164—west of Tremont, coals, method of mining, ii. 182, 183.
Little Mine Ridge, coal-beds, ii. 285.
Little Mine Run, ii. 272—to Big Run, ii. 273—coals, ii. 276.
Little Mountain, ii. 390, 399—contortions, ii. 403—red shales and sandstones, i. 292.
Little Norwegian Spohn Vein, ii. 40.
Little Peach Mountain Coal-seam, ii. 95.
Little Peach Orchard Coal, West Branch, ii. 217.
Little Perpendicular Coal-bed, ii. 128.
Little Quaker Run, ii. 286.
Little Sandrock Coal, ii. 139.
Little Saucon, crystalline rocks, i. 97.
Little Schuylkill Coal, ii. 227—Coal-measures, thickness of, ii. 82, 83—Company's estate, ii. 77—flexures of coal-field, ii. 96—through Fort Clinton, anti. flexures, i. 290—River to the Swatara, Verg. and Pon. rocks, i. 289—Sca. limest., i. 291—Surg. rocks, i. 290—to Swatara, Pon., Vesp., Umb., and Ser. rocks, i. 292—at Tamaqua, Coal-measures, ii. 69—Umb. red shales, ii. 6—Valley, mining details, ii. 66.
Little Scrub Ridge, i. 387—Cad. and Verg. rocks, i. 393, 428—Cad. and Verg. strata, i. 429—composition, i. 326, 415—Lev. sandsts., i. 324, 325—Mer. sandst., i. 424—Sca. and Prem. limests., i. 419.
Little Sugar Creek, Cad. sandst., i. 584—Loaf Mountain, ii. 242.
Little Swatara, trap rock, i. 255.
Little Toby Creek, ii. 486, 541—section, ii. 543.
Little Tomhicken Valley, ii. 241.
Little Tracey Coal, ii. 95, 121, 142, 143, 146—near Middleport, ii. 219—West-West Branch, ii. 174—drift, ii. 136.
Little Trough Creek, iron ore, i. 529.
Little Valley, i. 485—anti. axis, i. 466—iron ore, i. 73—Mat. slates, i. 486—Umb. limest., i. 530.
Livermore, ii. 600.
Liverpool, Pon. red sandst., i. 363.
Llewellyn coals, ii. 175—middle axis, ii. 162—north anti. axis, ii. 45, 161.
Loaded Track, coals, ii. 360.
Local erosion, ii. 927—of anti. ridges, ii. 933, 936—of mono. strata, ii. 929—ends of syn. valleys, ii. 937—of syn. belts, ii. 936—syn. gaps, ii. 938, 939.
Lock Haven, scenery, i. 50—Cad. and Verg. rocks, i. 540—Mer. slates, i. 539.
"Locking of the Mountains," i. 114, 314, 332—Lev. white sandst., i. 338.
Lock Mountain, i. 15, 19—anti., i. 554—Cove, i. 50—vertical position of strata, i. 505.
Lockport Hotel, Cad. rocks, i. 551—hills of Cad. rocks, i. 551—Pennsylvania Railroad, ii. 661—Pri. strata, i. 186.
Locust Gap, coal-seam, ii. 286—egg-conglomerate, ii. 277—Knob, ii. 277—Mountain, ii. 23, 48, 54, 65—anti. axis, i. 276—axis, Coal-measures, ii. 273—basin, ii. 29, 30—coal A, ii. 62—coal B, ii. 78—coal-basin, ii. 56—view of, i. 25—dip of strata, ii. 49, 308—mono., ii. 26—coal B, ii. 101—syn. trough, ii. 53—Ridge, dip of coal strata, ii. 26—syn. belt, lower red-ash coals, ii. 77—Run, flexures and coals, ii. 276—Valley, i. 118, 286—red shale, 225.
Logan, Eli's limestone quarries, i. 229—Sir William, ii. 802—Sir William cited, ii, 943.
Lomason Coal, Fisher's Basin, ii. 178.
London Grove Post-office, Pri. rocks, i. 229—township, Aur. limest., i. 229.
Long Creek Gap, Shade Mountain, i. 368.
Long Hollow, belt of limest., i. 417—Mer. sandst., i. 420—Ridge, i. 417, 426—Mer. sandst., i. 421—Surg. marls, i. 412.
Longitudinal ravines, ii. 932.
Long Narrows, i. 50, 369—Juniata, i. 51—ravines, i. 368—sketch, i. 32—Surg. slate, i. 376.
Long Pond, anti., i. 280.
Long Reach, Ohio River, ii. 16.
Long Run, ii. 525—Ridge, anti. axis, i. 291, 292—anti. flexure, i. 289.
Long's Mill, ii. 614.
Longstown Ridge, i. 396, 403—limest. quarries, i. 460—Surg. red shale, i. 458.
Loop, Mat. slate, i. 494—Mountain, Lev. sandsts., i. 482—Valley, i. 482.
Lorberry Creek, Rock Vein, ii. 166, 440—faulty condition of coal strata, ii. 185—fractures in coal strata, ii. 236.
Lorberry Gap, ser. series, i. 146.
Lost Creek Ridge, anti. axis, i. 370, 384—Prem. chert, i. 388—structure, i. 376.
Lost Creek Valley, i, 378, 384—Surg. strata, i. 376.
Loudon, anti. axis, Aur. limests., i. 315—limest. and iron ore, i. 269—and Mercersburg, anti. axis, i. 327.
Love's Gap, i. 489.
Lower carb. strata, ii. 756—Coal-measures, Lawrence County, ii. 501, 575, 609—conglomerate, ii. 680—Diamond Coal, ii. 131—Great Conglomerate, ii. 152.
Lower Helderberg limest., ii. 754.
Lower Rocks, south of Youghiogheny, ii. 612.
Lower Oxford township, serpentine, i. 170.
Lower Pri. rocks, unconformity to upper gneissic group, i. 74.
Lower Saucon Church, outcrops of limest., i. 234.
Lowest workable seam, ii. 461.
Lowrey's Knob, i. 419—near Hunter's Mill, i. 324, 326—Mat. slate, i. 479—Surg. ore, i. 415.
Lowrie's Well, Strattonville, ii. 570.
Loy and Patterson's Mine, ii. 460.
Loyalhanna, ii. 498, 502, 504, 603—River, i. 33, ii. 617—section, ii. 601—Umb. limest., ii. 473.
Loyalsock, ii. 508, 509—Creek, ii. 481, 510—Cad. and Verg. and Pon. rocks, i. 549—Pon. strata, i. 142—District, conglomerate, ii. 24—Gap, dip of white

sandst., i. 488—Surg. and Sca. rocks, i. 542—Valley, anti. axis, i. 308—Vesp. conglomerate, i. 302.
Loystown, anti. and syn. axes, i. 349—axis in Surg. shales, i. 316—Surg. marls, i. 340.
Lucerne Coal Co.'s Big Seam, ii. 355.
Lucinda Furnace, ii. 568, 569.
Luke Fidler Colliery, ii. 295—coal-seam, ii. 296.
Luthersburg, ii. 540, 545.
Luther Tunnel, Big Coal, ii. 104.
Luther's Slope Mine, ii. 416.
Lyberger's Run, i. 574.
Lyell, Sir Charles, mentions reptilian footprints, ii. 833.
Lyell's Elements of Geology cited, ii. 805, 808.
Lycoming County, mono. valley, i. 19—Creek, i. 308, ii. 482—anti. axis, i. 307—Cad. and Verg. and Pon. rocks, i. 549—iron ore, i. 541—limest. quarries, i. 309.
Lykens Valley Coal Company's mines, ii. 440.
Lyon Coal, ii. 109, 416.
Macaulay's Mountain, coal-basin, ii. 243.
McAllisterstown, i. 383, 385—Cad. slates, i. 392—Surg. rocks, i. 375.
Macleuria magna, ii. 817.
McCall's Ferry, i. 186, 187—lands, Twin Coal, ii. 304.
McCauley's Mountain, coal-fields, ii. 12.
McClure's Gap, i. 334.
McConnell's Cove, Aur. limest., ii. 4.
McConnellsburg, anti. axis, i. 324, 325.
McConnellsburg Cove, anti. axis, i. 419—Aur. limest., i. 324—structure, i. 323—Cad. and Verg. rocks, i. 428—iron ore, i. 479—Mat. and Lev. rocks, i. 326—fault along the north-west side, i. 325.
McConnellstown Cove, i. 114—Sca. and Prem. limest., i. 518—Sca. and Prem. limest., and Mer. sandst., i. 525—Surg. shales, i. 523.
McCoystown, Prem. chert, i. 388—Prem. limest., i. 385.
McCreary's Basin, ii. 154—Grey-ash Vein, ii. 156.
McCulloch's Run, ii. 615.
McDonald's Branch Dale Colliery, Spohn Vein, ii. 160, 161.
McDowell Banks, iron ore, i. 524.
McDuff's Grist-mill, i. 84.
McFarland's Mill, character of limest., i. 476.
McGee's Run, ii. 603, 616.
McGinnes' Boring, anti. axis, ii. 39.—Hollow, coals, i. 205, 206—mines, Jugular Coal, ii. 204—New Slope, ii. 132.
McGuide's Mill, ii. 602.
McKean County, i. 120—water-shed, i. 35, ii. 487.
McKey's Gap, i. 507—Surg. shales, i. 557.
McKeesport, ii. 637.
McKinney's Bank, iron ore, i. 499—ore-banks, limestone rocks, i. 497.
McMany's quarry of fetid limest., i. 544.
McMickle's Creek, Post-mer. limest., i. 284.
McMullen's, section at, ii. 659.
McMurtrie's Tavern, dip of Surg. strata, i. 513.
Madisonburg, anti. flexure, i. 493.
Madison Colliery, ii. 417—Sbipman's, ii. 418.
Magnesian rock, steatite and serpentine, i. 169
Magnetic iron-ore, ii. 713, 748.
Maguire's Ore-bank, i. 217.
Mahanoy Basin, ii. 6, 21—coal region, ii. 265, 270.
Mahanoy Mountain, i. 17, 23-25, 118, ii. 11—anti., ii. 289—monoclinal crest, i. 14, 15—Ridge, i. 361—Cad. grey sandst., i. 356—Cad. and Verg. rocks, i. 360—Sca. and Prem. limest. belt, i. 349—syn. belt, Verg. rocks, i. 452—Water-gap, Ser. conglomerate, ii. 273.
Mahantango Creek, Cad. and Verg. rocks, i. 391—Pon. red sandst., i. 395—Prem. chert, i. 389—Sca. and Prem. limest., i. 385—Mountain, i. 21, 118—ii. 11—Valley, ii. 7—Pon., Verg., and Cad. strata, i. 114—Pon. and Verg. strata, ii. 5.
Mahoning, ii. 587—Alleghany River valley, i. 51—Creek, ii. 493, 585—section, ii. 586—iron ores, i. 449—Pon. rocks, i. 452—Hill, i. 286—iron ore, i. 443—limestone, ii. 489, 567—Mountain, i. 289—Vesp. sandst., ii. 11—Ridge, 16th anti. in Verg. shales, i. 31—Valley, i. 289.
Mahoopeny Basin, i. 121—Creek, ii. 481, 510—Mountain, i. 120, ii. 480.
Mahoopeny's quarries, Lycoming Creek, i. 549.
Maiden Creek, i. 92, 102—cleavage Aur. limest., i. 102—slate hills, i. 249.
Main Black Creek Basin, syn. belt, ii. 263—Gate Coal, Mill Creek, ii. 135—Hazleton Coal-basin, ii. 256—Lower Coal, ii. 57—Slopes, i. 2.
Mammatt, Edward, cited, ii. 802.
Mammoth Coal, ii. 108, 146—Ashland Basin, ii. 274—M‘Ginnis's Hollow, ii. 206—St Clair, ii. 132—Coal Castle, &c., ii. 221.
Mammoth Salt-works, i. 604—Seam, ii. 427—John Dougherty's, ii. 168—White-ash Coal, Crow Hollow, ii. 134.
Manatawny Creek, iii. 681—Aur. limest., i. 200—Aur. limest. basin, i. 102—cleavage in Pri. slates, i. 102—east side of, i. 200.
Manaynnk, i. 5—gneissic rocks, i. 68, 79—Monokesy Creek, i. 93, 102—limest. and gneiss, i. 199—Hill's Inn, i. 200.
Manor Hill, i. 513.
Mansfield, ii. 524—iron ore, i. 311, 312—Verg. shales, i. 311.
Marble Hall, near Conshohocken, i. 162—quarries, i. 215—in Montgomery County, i. 167, 168—Mountain, i. 94—origin by metamorphism, i. 163—in quarry near Euphrata, i. 222—quarry, south of the Valley Turnpike, i. 215.
Marcellus group, ii. 755.
Margaretta Furnace, i. 185.
Maria Furnace, ii. 690—altered rocks, i. 206.
Marine fossils in limest. of coal, ii. 798—limest. in contact with coal, ii. 804.
Maris's Grist-mill, belt of serpentine and gneiss, i. 168.
Markle's Paper-mill, ii. 636.
Marls, i. 61.
Mar's Hill, anti., i. 514.
Marsh Creek, i. 545, 551, 552—Mer. sandst., i. 547.
Marshes of America, plants of, ii. 844.
Marshall Creek, cascade, i. 280—Mer. sandst., i. 282—Mill, serpentine, i. 169.
Marshallton, hornblendic gneiss, i. 78.
Martin Mountain, Sca., Prem., and Mer. strata, i. 509.
Martin's Bay, i. 506—Creek, Aur. limest., 242—Mat. arg. limest., i. 244—roofing-slate, i. 248.
Marvin Creek, ii. 549.
Mary-Ann Furnace, i. 267.
Mason's Drift, ii. 513—Tunnel, ii. 424.
Massey's Coal below Babylon, ii. 356.
Mastodon, ii. 773—giganteum, ii. 774—four grinders found south-west of Brown's Mill, i. 480.
Mather's Farm, limest. quarries, i. 213.
Matilda Furnace, iron ore, i. 412—Surg. foss. ore, i. 431.
Matinal arg. limest., i. 105, 112.
Matinal black slate, i. 112, ii. 784—in Anti's Gap, i. 490—on the Bushkill, i. 239, 249—in Centre County, i. 260—ten miles from Easton, i. 239—fossils, character and thickness, i. 105—Kishacoquillas Valley, i. 472, 478—Martin's Creek, i. 239—Nazareth, i. 239, 249—Union Canal, i. 249.
Matinal limest., Centre County, i. 239—Delaware River, i. 125—near the Delaware, i. 239—fossils, ii. 818—in Kishacoquillas Valley, i. 471, 472, 478—east of the Lehigh, i. 239—Martin's Creek, i. 239—Mifflin County, i. 239—Nittany Mountain, i. 493—near Swigert's Gap, i. 511.
Matinal newer slate, i. 112—Delaware River, i. 240—Kittatinny Valley, i. 239—organic remains, 240—Shade Mountain, i. 368.
Matinal period, ii. 749—physical geography of, ii. 783.
Matinal rocks, i. 124—near Bellefonte, i. 497—in Canoe Valley, i. 505—Jacksonville, i. 496—Kishacoquillas Valley, i. 462—Kittatinny Valley, i. 112—thickness, i. 472—at Tyrone Gap, i. 553.
Matinal series, ii. 752.
Matinal shales, i. 472, ii. 784—Canoe Mountain, i. 505—flexures, ii. 3—fossils, character and thickness, i. 105—Kittatinny Valley, i. 125—Kishacoquillas Valley, i. 478.
Matinal slates, i. 116—Althouse's Bridge, i. 252—Bernville, i. 254—Blacklog Valley, i. 370—boundary, i. 257—Brush Valley, i. 492—at Bunker's Hill, i. 254—between the Delaware and Schuylkill, i. 246—south-west part of Franklin County, i. 261—below Hamburg, i. 252—east of Harrisburg, i. 255—south of Irish Creek, i. 253—Jack's Mountain, i. 477—Kittatinny Valley, i. 125, 248—Kittatinny Valley, between the Susquehanna and Maryland, i. 260—north of Lebanon, i. 255—Lehigh Water-gap, i. 273—Maiden Creek, i. 249—Millerstown, i. 255—west of Monday Creek, i. 256—North Horse, Burns' and Amberson's valleys, i. 318—Northkill Creek, i. 254—Perry and Franklin Counties, i. 321—Plum Creek, i. 253—Reeser's Mill, i. 253—Rehrersburg, i. 254—west bank of the Schuylkill, i. 252—east of the Swatara, i. 255—second belt, i. 262——Seven Mountains, i. 481—Sugar Valley, i. 491—third belt, i. 262—Womelsdorf, i. 254.
Matinal strata, thicknesses of, i. 124, 126.
Matsan's Run, passage-beds, i. 165.
Mauch Chunk, ii. 23—coal-schutes, ii. 73—Creek monoclinal valley, i. 18—old tunnel, ii. 22—cost of preparing the coals, ii. 74—pictorial sketch, i. 29—Ser. series, i. 146—Vesp. strata, ii. 8—tunnel, contour of the eastern end of coal-basin, ii. 50—tunnel, Twenty-eight feet Vein, ii. 56—Umb. series, i. 144—Vesp. rocks, i. 143—Tunnel, white-ash coals, ii. 69.
Mauvaise terres, ii. 771.
Maxwell's Coal, ii. 374—mines, ii. 367—railroad, ii. 365.
Meadow Gap iron-ore, i. 371—Run, ii. 405.
Meadville, ii. 489, 558—Cad. and Verg. strata, i. 584—elevation of the hills, i. 578.
Mechanical structure of coal, ii. 800, 801.
Mecke's Tunnel, Jugular Coal, ii. 217—Western Tunnel, coals, ii. 208.
Medina red shale, ii. 753, 788.
Meek, Mr, ii. 759.
Megalomeryx, ii. 773.
Meganteris ovoides, ii. 826—Mendenhall's limest. quarries, i. 226.
Mercer, i. 120, ii. 564, 565—limestone, ii. 489—Sandy Lake, ii. 573.
Merichyrus, ii. 773.
Meridian period, ii. 749—rocks, i. 113—Black Oak Ridge, i. 561—north of Delaware Water-gap, i. 273—in Bald Eagle Valley, i. 539—Juniata, above Bell's Forge, i. 554—north of Lehigh Water-gap, i. 274—Lewistown Valley, i. 399—Perry County, i. 351, 352.
Meridian sandstone on anti. axes in Perry County, i. 352, 354—Bald Eagle Valley, i. 546, 547—belt in the third synclinal axis, i. 421—Broadhead's Creek to Steinberg, i. 284—north-east of Buckstown, i. 558—details, i. 424—fossils, character and thickness, i. 107—Ferguson's Valley, i. 417—iron ores, i. 410—Lehigh Water-gap, i. 137—limit, i. 409—Little Cove, i. 419—Pine Creek, i. 544—Prater's Ridge, i. 418—Stone Valley, i. 518—in Tuscarora syn., i. 388—Warrior Ridge, Pulpit Rocks, i. 519—north-west of Waynesburg, i. 420.
Meridian slate, character and thickness, i. 107—Tuscarora axis, i. 137.
Meridian strata, south-west of Bloomsburg i. 451—Lewistown, i. 401—between Jersey Shore and Muncy, i. 535—thicknesses of, i. 137, 138.
Meridian series, ii. 755—physical geography of, ii. 790.
Merista lævis, ii. 825.
Merrichippus, ii. 773.
Merrion Square, steatite and serpentine, i. 167.
Merwine's Tavern, Pon. red shales, i. 286.
Merycodus, ii. 773.
Mesozoic, boundary of, in Chester County, ii. 675—conglomerate at Neversink Hill, i. 103—formations, ii. 759—igneous rocks of, ii. 671—or Middle Secondary series, i. 257—of New England and Southern States correlated, ii. 697—and Palæozoic rocks in contact, ii. 681—red sandst., i. 100-102—ii. 760—dip of, ii. 670—composition of, ii. 667, 669—geographical limits of, ii. 667, 668—red shale near Coopersburg, i. 101—rocks, i. 59—east of the Schuylkill, i. 200—series, detailed description of, ii. 672, 675—strata, west side of Susquehanna, ii. 677, 761—near the Susquehanna, ii. 678, 679.
Metalliferous veins, ii. 706, 715—of Mesozoic, ii. 763.
Metamorphic Palæozoic strata, ii. 745—of Atlantic Slope of Middle and Southern States, i. 62.
Metamorphic rocks in Lehigh and Berks, i. 97—strata division, i. 64.
Metamorphism, origin of marble, i. 163.
Methodist meeting-house, ii. 375.
Mevey's Ore-bank, i. 423—Sugar Valley, i. 427, 433.
Mexican Gulf drainage, i. 40.
Mexico, south-east limit of Surg. and Sca. marls, i. 378.
Meyer's Tunnels on Bushy, ii. 112.
Mica in the Verg. rocks of the north-eastern district, i. 298.
Mica slate, limits and details, i. 77.
Micaceous gneiss in Bucks and Montgomery counties, i. 151.
Micaceous oxide of iron, ii. 679.
Michigan coal-field, ii. 967, 968.
Microdon bellastriata, ii. 827.
Middle Alabama, i. 119.
Middleburg, anti. axis, i. 405—block ore, i. 410—Ridge of limest., i. 403.
Middle carboniferous strata, ii. 757.
Middle Creek, ii. 438—anti. axis, i. 405, ii. 41—Aur. limest., i. 224—Black Heath Coal, ii. 216—Black Valley Coal, ii. 217—anti. flexure, ii. 165—egg-conglomerate, ii. 153—railroad, exposure of anticlinal S, ii. 167—Sca. limest., i. 401—of Swatara, ii. 154—white-ash coals, ii. 155, 156.
Middle Llewellyn axis, ii. 46.
Middle Norwegian anti. flexure J, ii. 143.
Middle Palæozoic strata wanting in Missouri, ii. 787.
Middleport, ii. 26, 414—anticlinal, ii. 33—coal-beds, ii. 115—Charles Pott Coal, ii. 113, 114, 218—Clarkson Coal, ii. 219—Palmer Coal, ii. 218—Small Coal, ii. 219—Spohn Coal, ii. 116—synclinal, ii. 32—syn. axis, ii. 35.
Middle Ridge, Cad. and Verg. rocks, i. 360—Pon. red sandst., i. 363.
Middle secondary red sandst., i. 92, 201, ii. 759.
Middle syn. belt of Wilkesbarre and Shickshinny district, ii. 383.
Middlesworth's Mill, Surg. rock and foss. ore, i. 411.
Middleton's Quarry, near French Creek, i. 583.
Middletown, ii. 613—North Valley Hill, middle zone of gneiss, i. 83.
Mid-Lothian coal-field, ii. 983.
Midway, Bell's Quarry, i. 214.
Mifflinsburg Mountain, i. 457.
Mifflintown, Sca. limest., i. 384—Sca. rocks, i. 135—Surg. red shale, i. 398—Surg. rocks, i. 132, 133, 134—Surg. strata, i. 373.
Milesburg Gap, Sca. and Prem. limest., i. 546—Surg. and Lev. rocks, i. 547—Mer. sandst., i. 548.
Millbaugh Hill, i. 112—General Section, No. 5, i. 93—Pri. rocks, i. 202.
Mill Brook, ii. 367.
Mill Creek, ii. 35, 370, 371, 376, 380, 420—Basin, features, dimensions, structure, ii. 223—Big Diamond Coal, ii. 218—Big Tracey Coal, ii. 40, 96—coal-basin, ii. 225—Coal-measures, ii. 229—Collieries, ii. 422—Spencer and Mason's Drifts, ii. 138—coal strata, ii. 123—geological section, ii. 36—Furnace anti., ii. 32—limest. full of fossils, i. 520—Gap, dip, ii. 235—Peach Mountain Basin, ii. 34—Palmer Coal, ii. 218—Primrose Coal, ii. 217—section, ii. 322—Small Coal, ii. 219—South Diamond Coal, ii. 218—steatite and serpentine, i. 71—synonyms of the coals, ii. 222—Umb. red shale, ii. 12—upper red-ash coals, ii. 135—Valley, mining details, ii. 84—to West Norwegian collieries and mining, ii. 145—details of the coals, ii. 152—Vesp. strata, i. 311.
Milford and Ben's Creek, section, ii. 657.
Milford Bridge, Post-mer. limest., i. 280—colliery, ii. 113, 414—Road, Post-mer. rocks, i. 282—Tunnel, syn. belt, ii. 32.

Millhall, dip of the Lev. rocks, i. 488—Gap, limest., i. 495—limest. quarry, section, i. 545.
Milk-and-Water Ridge, i. 527.
Miller's coal-beds, ii. 400—colliery, ii. 434—drift, ii. 513—mine, ii. 724—Lewis Coal, ii. 148—Mill, Dry Run belt of gneiss, i. 197—Phœnix slope, ii. 147.
Miller and Stahl's Phœnix Colliery, ii. 174.
Miller's Slope, Mount Laffy, Black Heath Coal, ii. 216.
Millerstown iron ores—Surg. rocks, i. 264, Lev. rocks, i. 337—Pre-mer. limest., i. 136—Pri. sandst., i. 196—Sca. limest., i. 330—Surg. block ore, i. 431.
Milliken's Cove, i. 117—anti. axis, i. 469—from Dry Ridge, pictorial sketch, i. 17—Lev. series, i. 128, 129, 130—Mat. limest. and slate, i. 125—Mat. slates, i. 511—pictorial sketch, i. 12—structure, i. 9—Surg. rocks, i. 560, 570—aspect of the Bald Eagle Mountain, i. 553—Knob, syn. trough, i. 513.
Milne's slopes, Big coal-seam, ii. 87.
Milne's and Snyder's new slope, ii. 132.
Milton, i. 116—Bridge, i. 457—Surg. red shale, i. 458—limest. quarries, i. 459—Sca. grey marls, i. 437—Sca. grey marl, thickness, i. 398—Sca. limest., thickness, i. 539—Sca. marls, i. 536—Surg. rocks, i. 132, 133, 134—Sca. rocks, i. 135.
Mineder's Mill, Pri. sandst., i. 198.
Mine Hill, ii. 3, 415, 442—anti., ii. 26—anti. wave, ii. 234—axis, ii. 52, 84—basin, ii. 20, 27, 443—Big Coal, ii. 200—structure and composition, ii. 201—south-western branch, ii. 211.
Mine Hill Gap, i. 84.
Mine Hill Gap colliery, ii. 168.
Mine Hill, structure, &c., ii. 199.
Mine Hill Valley, coals, and collieries, ii. 202—Ser. conglomerate, ii. 225, 442.
Mine in Primrose Coal-seam, ii. 1011.
Mine Ridge, composition and structure, i. 177—Pri. rocks, i. 111, 176.
Miner's Mill, ii. 369, 370.
Mineral Charcoal, ii. 993.
Minerals, ii. 709—in Aur. limest., ii. 712—developed by trap-dykes, ii. 685—of gneissic belts, ii. 748—of Mesozoic trap, ii. 671—of the metamorphic strata, ii. 711—and ores, ii. 710—in the South Mountains, i. 94—veins, ii. 700, 706, 709—near Phœnixville, ii. 699—of Wheatley Lode, ii. 701.
Minersville, ii. 428—anti., ii. 39, 40, 44—central axis, ii. 158—Lewis's Tunnel, Peach Mountain Coal, ii. 169—Little Diamond Coal, ii. 148—Griscom's axis, ii. 163—south axis, ii. 43—Tunnel, southern coals, ii. 159.
Miney Run copper ore, i. 207.
Mingo Creek, ii. 648.
Mining coal, ii. 1010—by slopes, ii. 1012.
Miocene fresh-water basin, ii. 772—strata, ii. 770.
Mississippi, lacustrine tracts, i. 38.
Missouri coal-field, ii. 964—river, ii. 771.
Mitchell's Drift, ii. 644.
Modiola concentrica, ii. 827.
Modiolopsis modiolaris, ii. 820.
Mohawk, marble beds, i. 239.
Monday Creek, Mat. slate, i. 255.
Monoclinal belts, how eroded, ii. 919—crests, instances, i. 14, 26—gaps, ii. 932—ridges, i. 13, ii. 920—examples west of the Susquehanna, i. 15—instances, i. 14—Kishacoquillas Valley, i. 15—valleys, i. 10—strata, local erosion of, ii. 929—Tuscarora Mountain, i. 331—valley at the south-east base of the Alleghany Mountain, i. 19—valleys, i. 15—around the anthracite coal-basins, i. 19—of the Appalachian chain, i. 18—how eroded, ii. 921—north-west of Kittatinny Mountain, structure, i. 18—scenery, i. 31.
Monokesy Creek, ii. 681.
Monongahela River, i. 51—City, ii. 641—Basin, i. 42.
Monroe, ii. 681.
Monroe from Easton (see Section A), i. 98.
Monroe Corners, limest. quarries, i. 309.
Montalto Furnace, i. 268, 269.
Montebello Furnace, 17th and 18th aut. axes in the Verg. slates, i. 317.
Montelius's Open Cut, ii. 1010.
Monterey colliery, ii. 447.
Montgomery and Chester limest. valley, i. 210, 211—Basin, marble quarries, i. 215—Pri. rocks, i. 60—Pri. strata, their composition, i. 154—syn. trough, ii. 2—lead-mine, ii. 676.
Montour ironworks at Danville, i. 444.
Montour's Ridge, i. 11, 14, 115—anti. axis, i. 440, 462—calcareous iron-ore, i. 449—character of the strata, i. 435—east of Hemlock Creek, i. 446—iron ores, i. 446—Mer. sandst., i. 137—Mer. slates, i. 438—Mer. slaty sandst., i. 451, 452—Pon. rocks, i. 440—Pre-mer. limest., i. 136—Pre-mer. rocks, thickness, i. 399—Sca. rocks, i. 437—scenery, i. 49—Surg. rocks, i. 436, 437—ii. 12—ores, ii. 730.
Montrose, Pon. and Vesp. rocks, i. 305—Vesp. sandst., i. 306.
Moore, Rev. W., Greensboro', ii. 835, 847.
Moore's Coal, ii. 356—opening, tabulated details, ii. 356.
Moore's Quarry above Lewisburg, Sca. grey marls, i. 536.
Mooretown, Mer. slates, thickness, i. 438—Pri. rocks, i. 77, 152.
Moosic Mountain, ii. 12.
Moravian Quarry, Cad. sandst., i. 583—Run, ii. 483.
Moreland's Hill, ii. 623.
Morgan's Corner, i. 168.
Morgan Hoffman's Farm, iron ore, i. 90.
Morgan and Edwards' Tunnel, ii. 434.
Morgan's Mill, gneiss rocks, i. 80—west of York's Factory, details (see Section), i. 160—Mine, ii. 361—Tunnel, ii. 42.
Morgantown, ii. 505—contortion of Aur. strata, i. 221—Virginia, ii. 501.
Morris Lode, ii. 700.
Morris Run, ii. 484—Section, ii. 519.
Morrison's Cove, i. 10, 523—anti. axis of the west side and south end, i. 468—anti. belt, ii. 4—anti. flexure, i. 506, 507—Aur. calc. sandstone, i. 123—Aur. limest., i. 470—Aur. rocks, i. 117—Mat. valley, i. 557—structure, i. 9.
Morrisville, Pri. rocks, i. 152.
Moselem Iron Mines, i. 266, ii. 726.
Moser's Valley, axis, i. 404.
Moser's and Swartzel's Valleys, anti. axis, i. 463—foss. ore, i. 410—Sca. limest., i. 401.
Moshannon, ii. 480, 481, 530—Section, ii. 531.
Mosquito Creek, ii. 561—Valley, i. 9.
Mosses of American peat-bogs, ii. 843.
Mount Braddock, ii. 505, 623—lands and section, ii. 622.
Mountain-belts, Lower Juniata, i. 114—Upper Juniata, &c., i. 116.
Mountain chain, general structure, ii. 1.
Mountain-coves in Centre County, i. 22—Union County, i. 22.
Mountain Creek, limest. belt, i. 205—Valley, Pri. rocks, i. 203.
Mountain-house coal, ii. 460.
Mountain-ridges and valleys, i. 10—sides, their aspects, i. 27—spurs of Union County, i. 485.
Mountains, passes or notches, i. 28.
Mount Carbon, Umb. red shale, i. 144, ii. 10.
Mount Carmel, ii. 287—anti. axis, ii. 278—anti. opposite Locust Gap, ii. 278—Basin, ii. 279, 280, 281—exposures of coals, ii. 288—details of the coals, ii. 290—subordinate basins, ii. 282, 283—Turnpike Coal-measures, ii. 283.
Mount Eagle Colliery, ii. 439.
Mount Hecla Bank, pipe ore, i. 499—Furnace, anti. flexure, i. 497.
Mount Hope Slope-mine, ii. 422.
Mount Jefferson, ii. 52.
Mount Joy, Pri. rocks, i. 173.
Mount Laffy, anti. details, ii. 38—Mammoth Seam, ii. 170—east slope, ii. 424—west slope, ii. 426—old tunnel, ii. 141—basin, details, ii. 38—coal, ii. 1003, 1005—tunnel, ii. 147.
Mount Moriat, Vesp. conglomerate, i. 304.
Mount Pisgah, i. 245, ii. 49—inclined plane, ii. 74—Coal-measures, ii. 69—and Hell Kitchen Basin, ii. 50—near Mauch Chunk, pictorial sketch, ii. 1, 12—syn. knob, ii. 26.
Mount Pleasant, ii. 481—old forges, i. 201—old ore-bank, i. 315—fault, i. 320, ii. 506, 532, 620—iron-mine, ii. 715—Tavern Daniel Coal, ii. 211.
Mount Sorrow, Pri. white sandst., i. 173.
Mount's Creek, ii. 504, 506, 609, 620.
Mowray's Run, ii. 308—anti. axis, ii. 289.
Moyer's Coal, ii. 619.
Mud Turnpike, outline sketch, i. 34.
Muddy Branch, ii. 434—anti. axis, ii. 167—Griscom's axis, ii. 172—Spohn Vein, ii. 161—white-ash coals, ii. 153.
Muddy Creek Hollow, ii. 153, 646, 647—anti. flexures, i. 187.
Muncy, anti., i. 488—Bridge, Sca. marls, i. 536—Cad. and Verg. rocks, i. 540.
Muncy Creek, Sca. marls, i. 538—Surg. and Sca. rocks, i. 542.
Muncy Hills, Cad. upper black slate, i. 140—Cad. and Verg. strata, i. 548—character of the strata, i. 439—Mer. sandst., i. 547—pictorial sketch, i. 50—Pre-mer. and Mer. strata, i. 535—scenery, i. 30—sync. belt, Cad. and Verg. rocks, i. 454, 455—syn. trough, Prem. limest., i. 453.
Muncy Lock, Cad. black slate, i. 548.
Muncy, Mer. rocks, i. 137, 138—Pre-mer. limest., i. 136.
Muncy Mountain, i. 535.
Muncy Town, Sca. rocks, i. 135.
Muncy, Sca. limest., i. 539.
Munroe Corners, ii. 512.
Murchisonia bicincta, ii. 817.
Muscites, ii. 849.
Musquito Valley, Lev. rocks, i. 489.
Musser's limest. quarry, i. 257.
Mylin's Ore-pit, i. 217, 219.
Nanticoke, scenery, i. 48—Mill, ii. 378—Mountain, i. 29—section, ii. 399—Seral series, i. 148—Umb. red shale, ii. 320—Umb. series, i. 145.
Nantmeal Township, Aur. limest., i. 232.
Napoleon Mine, ii. 676.
National Road, ii. 506, 623.
Nature of the coal strata, ii. 796.
Nautilus decoratus, ii. 833.
Nebraska, cretaceous deposits, ii. 766—Miocene basin, ii. 771—Pliocene strata, ii. 773.
Neeley's Sawmill, Mer. sandst., i. 390—Prem. limest. and Mer. sandst., i. 387.
Negro Mountain, i. 3, 32, 33, 120, ii. 494.
Negro Valley, Lev. and Surg. rocks, i. 377—Sca. limest., i. 419—Surg. rocks, i. 413.
Neill's Slope, ii. 121, 419.
Neobrara, ii. 764.
Nephrite, i. 95.
Nesbitt's Coal, ii. 411.
Nescopeck Mountain, i. 48, ii. 11, 12—mono. crest, i. 15—the Vesp. strata of, ii. 8—Passage-group of rocks, ii. 9—Vesp. conglomerate, i. 302—Vesp. rocks, i. 143.
Neshanning stone quarries, i. 153.
Neshannock Creek, ii. 400, 565.
Neshannon, ii. 574.
Nesquehoning, Broad Mountain, composition, structure, i. 118—coal-beds, ii. 213—mines, coal-seams, ii. 57—condition of the coal, and modes of transport, ii. 54, 56—synonyms of the coals, ii. 221—Mountain, i. 286—Vesp. rocks, ii. 6—Seral series, i. 146—Tunnel, ii. 51—white-ash coal, ii. 67, 69.
Neversink Hill, Aur. limest., i. 199—structure, i. 7, 103, ii. 681—spurs, i. 94.
Neville's Mine, ii. 115.
Nevin's Quarries, i. 82—limest. Quarries, i. 225—Quarry, i. 226.
Neuropteris, ii. 856, 857, 858, 859.
New Alexandria, ii. 602—section, ii. 630.
New Bethlehem, ii. 585.
New Berlin, i. 115—Gap, i. 458.
Newberry, ii. 688.
New Burlington, Prem. and Mer. rocks, i. 404.
Newcastle, ii. 566, 576—coals, ii. 202—coal-field, ii. 981—colliery, ii. 442—mine slate, i. 204.
New Chester, ii. 688.
New Columbia, limest. beds, i. 458—Post-mer. anti. belt, i. 452.
New Cumberland, Aur. limest., i. 257.
New Derry, ii. 617.
New Geneva, ii. 626, 647.
New Haven Mine, ii. 370, 380.
New Holland, character of Aur. limest., i. 221—limestone, i. 193.
New Hope, trap-rock, i. 48—Turnpike, Old Plumbago Mine, i. 81.
New Horne Coal, ii. 259.
New Iron Furnace, No. 2, i. 75.
Newkirk, axis B, see Fig., ii. 97—Colliery, Reinhardt's Run, Grier Coal of Tuscarora, ii. 216—synonyms of the coals, ii. 222—Tunnel, Coal E, ii. 79—Coal E, section, ii. 98—Coal E, ii. 99—Coal F, details, ii. 99—Coal D, ii. 101—details, ii. 102, 213, 214, 215.
New Liberty, Cad. rocks, blue, pyritous, &c., i. 551.
Newlin Township, limest. quarries, i. 230—serpentine belt, i. 170.
New Mine, ii. 331.
New Philadelphia, syn., ii. 32—Preston's Colliery, ii. 118.
Newport Centre, ii. 376, 384—anti., ii. 387—coals, ii. 388, 398.
Newport on the Juniata, 9th anti. axis in Cad. rocks, i. 316.
New Slope, ii. 331—details, ii. 102.
New Texas, Serpentine Barrens, i. 171, 172.
Newton Hamilton, i. 50, 426—Mer. rocks, i. 137, 138, 399—Mer. sandst., i. 422—Prem. limest., i. 136—Prem. rocks, i. 399—Sca. grey marl, i. 398—Sca. limest., i. 398—Sca. marls, i. 398—Sca. rocks, i. 135—Surg. red shale, i. 398—Surg. rocks, i. 134.
Newtown, ii. 376—Bed, ii. 386.
New Tripoli, Slate Hills, i. 249.
Newville, anti. axis, i. 257.
New York and Pennsylvania Coal Co.'s Slope Mine, ii. 355.
Niagara limest. fossils, ii. 824—group, ii. 754.
Nichol's Bank, ii. 618.
Nickel and copper mine, ii. 1022.
Nigger Heads, near Honesdale, i. 304.
Nine-mile Run, ii. 604.
Nineteen-feet Coal, ii. 58.
Niobrara, ii. 771—Fresh-water Basin, ii. 772.
Nippenose Valley, i. 9, 126—Creek, Cad. black slate, i. 550—Surg. strata, i. 543—Oval Valley, Lev. sandsts., i. 488—Mat. series, i. 125—Mat. limest., i. 472—ravines, i. 489—structure, i. 490.
Nittany Mountain, i. 485, 488—Mat. slates, i. 456, 495—North Terrace, i. 486—Lev. grey sandsts., i. 484—syn. dip, i. 498—syn. spur, i. 13—Ridge, i. 492—Valley, i. 9, 116, 126, 484, 485—anticlinal, i. 489, 553—S. E. side, i, 467—flexures, i. 494, 495—Aur. calc. sandst., i. 123—Aur. mag. limest., i. 124—axis, ii. 4—details, i. 500—iron ore-beds, pipe ore, i. 499—Aur. limest., i. 470—main axis, ii. 467—Mat. limest., i. 472—Mat. series, i. 125—road to Sugar Valley, i. 487, 488—Southern anti., i. 504.
Noble's Creek Bank Coals, ii. 337.
Nockamixon, altered red shales, ii. 686, i. 5—scenery, i. 48.
Nodular iron ores in Upper Coal-measures, ii. 359.
Noeggerathia, ii. 854.
Nomenclature of the Palæozoic strata, ii. 749.
North of Easton, i. 94.
North American Co.'s Mines, ii. 146.
Northampton oolitic limest., i. 238.
North Beaver Meadow Basin, Big Coal, ii. 251.
North Branch, i. 120—drainage, i. 35—valley scenery, i. 37—of Susquehanna, Cad. and Verg. rocks of the anticlinal belt, i. 452.
North Carolina Mesozoic fossils, ii. 696—Pliocene and Pleistocene, ii. 772.
Northdale Slope Colliery, ii. 415.
North Diamond Bed, ii. 119, 120, 128, 134, 147.
North-east, village of, org. remains in the Verg. strata, i. 583.
North-eastern district, i. 303.
Northern anthracite coal-field, ii. 318.

Northern belt of gneiss, i. 93.
Northern Branch Basin, ii. 255.
Northern coal-field, ii. 329.
Northern Pleistocene, ii. 774.
Northern Tuscarora Saddle, ii. 30.
North Gate Coals, ii. 135—in Pinkerton's Tunnel, ii. 126.
North Horse Valley, i. 114—anti. axes, Mat. slates, i. 314, 317—Mat. slate, i. 321—Lev. rocks, i. 328—third belt of Mat. slate, i. 265.
North Inverness and Victoria coal-field, ii. 952.
Northkill Aur. mag. limest., i. 252.
North Mountain, i. 455—Mat. slate, i. 260—Lev. sandst., i. 260—outcrops of coals, ii. 314—south-dipping coals, ii. 193.
Northumberland, red sandst. cliffs, i. 50.
North Valley Hill, i. 181—Pri. series, i. 122—Pri. rocks, i. 180, 150, 151—Pri. white sandst., i. 156, 173—Pri. rocks, i. 173—Primal strata, i. 176.
North-west Belt, i. 133.
Norwegian Basin, ii. 40—Orchard Coals, ii. 169—Peach Mountain axis, ii. 39.
Norwood, Dr, cited, ii. 959, 960—quoted, ii. 964.
Notch Mountain, i. 484.
Notches or passes in the mountains, i. 28.
Nottingham coal-field, ii. 980.
Novelty Colliery, ii. 416.
Nucula ? ii. 833.
Numulite, ii. 769.
Oak Grove Furnace, i. 334—Cad. sandst., i. 362—iron ore, i. 343—Mer. sandst., i. 354—Sca. and Prem. limests., i. 350.
Oakdale Colliery, ii. 419.
Oak Hill, anti. axis, 42—Coal, Wolf Creek, ii. 169, 427—slope, ii. 425.
Oblique stratification from suspension, ii. 813.
Octahedral iron, Safe Harbour, i. 187.
Octorara Creek, Pri. strata, i. 176—serpentine belt, i. 170.
Odd Fellows' Hall, coals, ii. 345—Scranton, ii. 343.
Odontopteris, ii. 860.
Ohiopyle Falls, i. 34, ii. 664.
Ohio River, ii. 581—Basin, i. 42, 120—structure and scenery, i. 36—north tributaries, i. 577.
Oil Creek, i. 577, 578.
Oil Creek Lake, i. 39.
Old Breaker Schute, ii. 111.
Old Fort, i. 493.
Old Tunnel, ii. 50.
Olean, ii. 547—Pon. strata, i. 142—Vesp. rocks, i. 144.
Oley Township, Aur. limest., i. 200—Furnace, Pri. sandst., i. 198—Pri. slate, i. 200.
Oliphant's Furnace, ii. 504, 625.
Oliver's Colliery, ii. 437—Bare Ridge, ii. 127—Peaked Mountain, ii. 208.
Onchus Deweii, ii. 824.
Oneida conglomerate, ii. 788.
Onondaga salt group, ii. 754.
Oolitic coal-basin of North Carolina, ii. 764—limest., near Allentown, i. 238—examples, i. 236.
Open Cut Mine, ii. 245.
Opossum Creek, Pri. white sandst., i. 204.
Orbicula, ii. 818—minuta, ii. 826.
Orbison's Coal, ii. 453.
Orbisonia, i. 370, 371—Cad. black slate, i. 427.
Orbitoides, ii. 769.
Orchard Bed, ii. 410, 131, 141, 130—Old Drift, ii. 280, 285.
Ore, Wheatley Mine, ii. 704.
Oreodon, ii. 771.
Ore-pits, ii. 726.
Ore sandst. in Stone Valley, details, i. 516.
Ores and minerals, ii. 710, 712.
Organic remains, ii. 694, 696, 773—Aur. limest., i. 471—geological age of Mesozoic red sandst., ii. 760—of Missouri coal-field, ii. 967—of N. American cretaceous strata, ii. 766—of the Palæozoic strata, ii. 815—in the Pon. rocks, i. 300—of red sandst., ii. 692—of red sandst. belt of Pennsylvania, ii. 695—in the Verg. flag formation, i. 296—Verg. shales, i. 298—Vesp. conglomerate, i. 302—near Waterford, ii. 583.
Origin of iron ores of Coal-measures, ii. 737, 738—Mesozoic red sandst., ii. 761, 762—the Pri. strata, ii. 780—of coal strata, ii. 805.
Oriskany sandst., ii. 755.
Ormoceras crebriseptum, ii. 821.
Orographic regions, i. 3.
Orography of Fifth District, i. 39—First District, i. 4—Fourth District, i. 36—Second District, i. 5—Third District, i. 32.
Oromucto Lake, ii. 945.
Orr's Valley, i. 403—anti. flexures of strata, i. 475—Aur. limest., i. 478—Lev. rocks, i. 476—Perryville, axis, i. 464.
Orthis elegantula, ii. 823—pectinella, ii. 818—testudinaria, ii. 818.
Orthonota undulata, ii. 827.
Orthoceras imbricatum, ii. 823—multicameratum, ii. 817—subulatum, ii. 826—vertebrale, ii. 819.
Orwigsburg anti. flexure, i. 289—and Stroudsburg Valley, i. 113—structure, i. 270, 271.
Orwigsburg, Surg. sandst., i. 291.
Ostrea sellieformis, ii. 769.
Otodis, ii. 769.
Otter's Run, ii. 518.
Otto Mines, ii. 434—White-ash Seam, ii. 435.
Outcrop of the coals, ii. 412—in Sixth Basin, ii. 490—deflected by erosion, ii. 930—Lower Freeport Coal, ii. 576.
Owen, Dr D. D., cited, ii. 961, 965—Geological survey, ii. 787.
Owen's Ridge, i. 423—limest. belt, i. 418.
Owl Hole, ii. 261.
Oxide of manganese, i. 304.
Pachyphyllum, ii. 863.
Pacific Slope, ii. 767.
Paddy's Mountain, i. 481, 482—iron ore, i. 459.
Paddy's "Path Valley" Mountain, origin, range, i. 457.
Paddy's Run, ii. 483.
Paine's Tunnel, ii. 204.
Paint Creek section, ii. 655.
Painter's Salt Well, ii. 605.
Palæochærus, ii. 771.
Palæoniscus, ii. 947.
Palæontological break at close of Mat. period, ii. 788—close of Pri., ii. 781—horizon, i. 63.
Palæozoic age demonstrated, i. 63—denudation, ii. 659—formations, ii. 748—region, Eighth District, i. 117—Fifth District, i. 114—First District, Pri. and Aur. rocks, i. 111—Fourth District, i. 113—Ninth District, i. 119—Second District, i. 112—Seventh District, i. 117—Sixth District, i. 116—structural features and boundaries, i. 110—subdivision, i. 110—Third District, i. 113—rocks, i. 59, 60, 64—Pennsylvania, i. 110, 111, 122—Chique's Ridge, i. 195—Cleavage, i. 102—defined, i. 104—how formed, ii. 811—Spring Mill, i. 76—strike, near Easton, i. 245—types of, i. 122, 148.
Paliosaurus, ii. 695.
Palmer Coals, ii. 32, 113, 125, 135, 145—at Milford Colliery, &c., ii. 218—on Singley's Farm, ii. 137—thickness, ii. 103, 414.
Palmer's Tunnel, ii. 413—details of coals, ii. 215—Grey-ash Group, ii. 103, 106.
Panther Creek, anti. origin, ii. 51—basin of the bed, red-ash coals, ii. 62—coals, synonyms, ii. 221—south anti., ii. 29—south boundary, ii. 50—tunnels, ii. 74—tunnel No. 9, ii. 74, 75—tunnels, mining details, ii. 66—white, grey, and red-ash coal, ii. 69.
Paoli, serpentine belt, i. 168—upper Pri. slate, i. 180.
Paradoxides spinosus, ii. 816.
Parallelism of crust-undulations, ii. 886—of faults to axis-planes, ii. 897.
Parkesburg, Pri. series, i. 122.
Parnell's Knob, i. 26, 336—limest. belt, i. 261—Mat. slate belt, i. 261—Surg. slates, i. 345.
Paroxysmal actions in coal period, ii. 808.
Pasco Coal, ii. 109, 416.
Passes of the Appalachain Chain, i. 29.
Pat Martin Coal, Bear Gap, ii. 192.
Path Valley, i. 9, 114, 318, 331—anti. axis, Mat. slates, i. 314—anti. belt, ii. 4—Aur. limest., i. 320; ii. 4—Lev. sandst., i. 332—Mat. slate, i. 321—on south-east side, i. 323—north-west of the fault, i. 322—third belt of limestone, i. 262.
Patrick's Upper Mine, ii. 452.
Patterson, slopes north-west of the village, details, ii. 104.
Patterson, anti. axis, ii. 89—basin, ii. 31, 109—Colliery, ii. 443—Farm, Aur. limest., i. 479—iron ore, i. 479.
Patterson and Middle St Clair, anti. axis, ii. 32.
Patterson's Mill, ii. 589—Cad. and Verg. rocks, i. 393.
Patterson's Valley Mill, Prem. chert, i. 388—Prem. limest., 385.
Payne's Colliery, Crosby Coal, ii. 221—Jugular Coal, ii. 217.
Pea conglomerate, ii. 147.
Pea and Nut conglomerate, east of Belmont, ii. 129.
Peach Bottom, slate belt, i. 186, 188.
Peach Mountain, axis of Norwegian, ii. 39—southern subordinate saddle, ii. 96.
Peach Mountain Basin, ii. 39, 41, 112—details of the coals, ii. 124—outcrops of coals, ii. 93, 142—structure, ii. 34.
Peach Mountain Bed, ii. 426—belt, subordinate anti., ii. 157—Coal, ii. 34, 94, 111, 121, 128, 142, 143, 146, 158, 228—dislocation, ii. 237—Red-ash Group, ii. 18—(Delaware Mines,) ii. 148—Middleport, ii. 116—west of Middleport, &c., ii. 219—west side of Mill Creek, ii. 134—Phœnix Colliery, ii. 39, 174—folded anti. flexure, ii. 34—inverting axis, ii. 159—Kantner axis, ii. 157—Seam, ii. 428—Vein, red-ash coals, ii. 110, 159.
Peach Orchard Coal, ii. 147—Colliery, ii. 428.
Peacock Coal, ii. 137—Mill Creek, ii. 174, 219.
Peaked Mountain, anti. axis, ii. 210—Colliery, ii. 446.
Peat-bogs, ii. 845—of North America, ii. 843.
Pebbles of the Mat. strata in Lev. sandst., i. 277—Pri. strata in Lev. sandst., i. 277—white quartzose conglomerate, i. 152.
Pecopterideæ, ii. 864.
Pecopteris, ii. 866, 867.
Pecquea, i. 176—Basin, i. 177—and Conestoga Valley, local limest. basins, i. 217, 218.
Pence's Openings, i. 490.
Pencil Coal, ii. 59—Vein, ii. 54.
Penn Coal Company, ii. 371.
Penn's Creek, Fathomless Spring, i. 494—Creek, Sca. limests., i. 401.
Pennsborough, Sca. marls, i. 538—Sca. and Prem. limest., i. 535.
Penn's Mount ore-vein, ii. 716—Mountain, Pri. white sandst., i. 197—Narrows, anti. axis, i. 465—South Mountain, i. 94—Valley, i. 9, 116, 484—anti. axis, i. 457—anti., i. 482—anti. axis, i. 493, 494—north western anti. axis, i. 465—anti. flexure, i. 514.
Pennsylvania coal strata, ii. 13—Company's new mines, ii. 373—furnace, of limest. rocks, i. 501—railroad track, i. 13—Slate Company's quarry, i. 248.
Penny Hill, Cad. olive slate, i. 455—Verg. flags, i. 540.
Pennypack Creek, gneiss, i. 80—Pri. rocks, i. 80—Pri. series, i. 152.
Pentamerus galiatus, ii. 825.
Pentremites, ii. 833.
Perkiomen Creek, ii. 681—limest. quarries, i. 201—Pri. white sandst., i. 201.
Perkiomen, faults, i. 86—lode, ii. 700—mines, ii. 699—Turnpike, i. 165—anti. axis, i. 162—Aur. limest. quarry, i. 199.
Permian age imputed to N. Carolina Mesozoic, ii. 697—formations, supposed, ii. 759—rocks, i. 60—strata, Illinois coal-field, ii. 963.
Perpendicular coal, ii. 39, 121—Crow Hollow, ii. 131.
Perpendicular deposition, ii. 812.
Perry or Brook's Coal, ii. 128.
Perry County, i. 138, 139—anti. belt, i. 114—geological structure, i. 313—Mer. rocks, i. 137—Mer. strata, i. 351—Sca. limest. i. 135, 330—Sca. and Prem. limests., i. 345—Sca. variegated marls, i. 329—Surg. lower or older ore shale, i. 329—Surg. ore sandst., i. 329—Surg. red shale, i. 329—Surg. rocks, i. 132, 133, 134—upper or newer ore shale, i. 329—Verg. shales, i. 141—Surg. rocks, i. 328.
Perry Furnace, anti. axis in Verg. shales, i. 316—Cad. and Verg. rocks, i. 360—Ore Bank, tenth anti. axis, 316—Mer. sandst., i. 353—Prem. limest., i. 349, 350—ridge of Cad. grey sandst., i. 342.
Perryopolis, ii. 611, 639.
Perryville, anti. axes, i. 476—Cad. black slate, i. 393—Character of the flexures, i. 477—dip of strata, i. 476—Prem. chert, 388—Prem. limest., i. 385.
Perseverance Vein, Rattling Run, ii. 198.
Peter's red-ochre mine, i. 200.
Petersburg, ii. 679, 683—and Carlisle Turnpike, i. 204—limest. quarry, i. 223.
Peter's Mountain, i. 21, ii. 11—mono. crest, i. 14—Pon. red sandst., i. 363—Vesp. rocks, i. 143.
Petherick coal-seams, ii. 430.
Petroleum, i. 583.
Pfout's Valley, i. 337—Cad. and Verg. rocks, i. 391—Mer. sandst., 351—north-west side, Sca. and Prem. limest., i. 385—to Peter's Mountain, i. 345—Prem. chert., i. 389—Sca. and Prem. limest., i. 346—Surg. slates and Sca. marls, i. 380.
Pheasant Valley, dip of strata, i. 487—Surg. shales and slates, i. 485.
Phelp's Mine, ii. 356.
Phenomena connected with coal-seams, ii. 799.
Philadelphia, climate, i. 55—gneissic rocks, i. 68—temperature, i. 56—serpentine used for street-door steps, i. 168.
Philipsburg, ii. 481, 531.
Philipsport, ii. 582.
Phœnix Bed, ii. 428—Colliery, ii. 432—details of coals, ii. 174.
Phœnix Mines, ii. 154, 155—south coal, ii. 158, 159.
Phœnixville, ii. 700—mineral veins, ii. 699—Tunnel, ii. 696.
Phœnixville, faults, i. 86.
Physical geography of the Cretaceous Era, ii. 767—the Eocene Era, ii. 770—of Palæozoic strata, ii. 776.
Physical Geography, i. 1.
Pickering Creek, ii. 676, 699—Aur. limest., i. 231—faults, i. 86.
Pictorial sketch of environs of Canonsburg, i. 36—from Fair View Inn, i. 32—Kishacoquillas Valley, i. 10—of Kittatinny, Mahoning, and Sharp mountains, i. 9—of Lock Mountain Cove, i. 30—of Milliken's Cove, from Dry Ridge, i. 12—of Mount Pisgah, i. 12—of Mud Turnpike, i. 34—of a pass below Mauch Chunk, i. 29—view of the termination of Canoe Mountain, i. 13—of the scenery at the Delaware Water-gap, i. 47—of Huntingdon from Warrior Ridge, i. 139—of eastern end of Kishacoquillas Valley, i. 13—of Lehigh Water-gap, i. 29—of the Lewistown Valley, i. 50—of Miliken's Cove, from Dry Ridge, i. 17—Muncy Hills and White-deer Mountain, i. 50—of Pittsburg, &c., i. 36—of Susquehanna River, at the gap of the Second Mountain, i. 49.
Pictou coal-field, ii. 948, 950.
Picture of Alleghany Mountain, from near Hollidaysburg, i. 13—of Shade and Blue mountains, i. 32—of Stone Ridge, at the canal, i. 50.
Pigeon Cove, i. 411—anti., i. 115—anti. axis, i. 397—Cad. and Verg. rocks, i. 428—Mer. sandst., i. 423—Sca. and Prem. limests., 419—Surg. marls, 414.
Pigeon Hills, ii. 680—limest. quarries, i. 223—Pri. rocks, i. 111—York Valley, i. 195.
Pike Run, ii. 642—Township, i. 200.
Pilgrim Iron-ore Bank, i. 268.
Pilot Hill, i. 334, 342—anti. axis, i. 317.
Pimple Hill, Pon. rocks, i. 286.
Pine Brook Basin, ii. 352.
Pinebrook Mines, coals, ii. 343—subdivisions of the coal, ii. 351.
Pine Creek, i. 49, 457, ii. 1, 482, 483, 486, 524, 525—anti. axis, i. 308—anti. valley, i. 286—Aur. limest., i. 200—Bottom, double anti. axis, i. 544—Cad. olive slates, i. 550—First Fork, ii. 511—gneiss rocks, i. 198—limestone ridge, i. 535—Sca., Prem., and Mer. Surg. rocks, i. 544—view opposite Smith's Gap, i. 278.

Pine Forest Slope, ii. 421.
Pinegrove, ii. 23—Cad. shales and sandstone, i. 287—Furnace, limestone, syn. axis, i. 203—Pon. red sandst., i. 293—Pri. rocks, i. 204.
Pine-knot Colliery, ii. 443—Daniell Coal, ii. 204.
Pine Ridge, i. 286, 361—axes, i. 564—Mer. sandst., i. 558—Pon. strata, i. 364—ridge, i. 514.
Pine Run, ii. 588.
Pine Swamp Run, ii. 407.
Piney Creek, i. 506—Hill, Pon. rocks, 521—Ridge, i. 526.
Pinkerton's Coal-seam, ii. 295—Tunnels, Bare Ridge, ii. 126—Tunnel, St Clair, ii. 132—Upper Tunnel. ii. 34.
Pinnularia, ii. 848, 878.
Pipe ore, Nittany Valley, i. 499.
Pisgah Hill, Cad. grey sandst., i. 356—Cad. sandst., i. 361—Mer. sandst., i. 354.
Pismire Hill, ii. 244—Ridge, anti. range, ii. 239.
Pittsburg, ii. 493, 505, 630—Alleghany River, i. 51—Coal, ii. 604, 611, 634, 636, 637, 638, 642, 644, 648, 649—along the Redstone, ii. 624—Bed, ii. 498, 503, 606, 616—south-west from Redstone Creek, ii. 625—Cat Run, ii. 627—Cheat River, ii. 626—columnar structure, ii. 661—first sub-axis, ii. 626.
Pittsburg Coal, Greensburg, ii. 629—coal south of Jacob's Creek, ii. 620—Laurel Hill Gap, ii 626—Millar's Bank, ii. 629—National Turnpike, ii. 627—Newcomer's, ii. 627—Seam, ii. 504, 617—area of, ii. 958—coal south of Sewickley, ii. 619—Smithfield, ii. 627—Virginia Line, ii. 626—south of Youghiogheny, ii. 622—limestone, ii. 634—newer Coal-measures, ii. 19—older coal-shales, ii. 19—pictorial sketch, i. 36—sandstone, ii. 505—section at, ii. 631—strata at, ii. 632.
Pittston, i. 48, ii. 326, 355, 371—anticlinals. ii. 372—Coal-bed. ii. 322—Coal-measures, ii. 361—district, details of coals, ii. 329—Gap, ii. 405—7-ft. coal, ii. 362, 363.
Plane Number 2, ii. 364—22, ii. 363.
Planesville, ii. 375—axis, ii. 365.
Plank Cabin Valley, ii. 449—Umb. limest., i. 530—Umb. red shales, i. 532.
Plank Road, ii. 368.
Plants of coal strata, ii. 841.
Plateaus, benched, ii. 918—with simple escarpments, ii. 918.
Platt Coal, Wolf Creek, ii. 172.
Platyostoma, ii. 825.
Pleasant Lake. i. 39—Valley limest. quarries, i. 227.
Pleistocene of California, ii. 773—foss. clays, ii. 775—fresh water of Western States, ii. 775—strata, ii. 772.
Pleurotomaria, ii. 833—bilex, ii. 820—subconica, ii. 819.
Pliocene fossils, Nebraska, ii. 773—strata, ii. 772.
Plumbago Coal-bed at the West Branch Gap, ii. 170—Old Mine, Bucks County, i. 81—Seam, ii. 234.
Plunkett's Creek. ii. 481—Cad. black slates, &c., i. 551.
Plunkett's Run, Mer. sandst., i. 547.
Plymouth Bed, ii. 407—belt, ii. 407—Great Bed, ii. 409.
Po Valley anticlinal. i. 481, 482—axis, i. 464.
Pœbrotherium, ii. 771.
Pogopogo Creek, Verg. and Pon. rocks, i. 275.
Pokono Knob, Cad. rocks, i. 285—or Catskill Mountain, i. 280—Creek, i. 285—Knob, Pon. rocks, i. 286—structure, i. 303—Mountain, i. 18—Vesp. sandst., i. 12—Pon. rocks, i. 300.
Poleeat Valley, i. 334, 362.
Polish Mountain, i. 528.
Pomeroy Coal-seam. Carr's Run, ii. 16.
Pond Bank, iron ore, i. 500—furnace, i. 267—iron ore-banks, i. 268.
Ponds and lakes, i. 38.
Ponent period, ii. 749—red rocks, junction of Cove and Licking creeks, i. 430—sandst. between Belmont and Stockport, i. 306—between Bethany and Mossic Mountain, i. 304—North-west of Harshey's Mill, i. 430—Lewistown Valley, i. 400—S.W. of Littleton, i. 430—fossils, organic remains, i. 108—below Selinsgrove, i. 395—red shale, ii. 547—rocks, i. 113, ii. 485, 520, 546—Bald Eagle Valley, i. 541, 549—Caskill or Pokono Mountain, 299—west and south-west of Chestnut Ridge, i. 565—above Damascus, i. 304—on the Delaware, i. 304—from Delaware Water-gap to Wind-gap, i. 286—near Ellisbury, i. 142—in Fourth District of the Palæozoic region, i. 113—near the Great Eddy, i. 304—South-west of Hollidaysburg, i. 559—south-east of Honesdale, i. 304—north-west of Kittatinny Mountain, i. 141—north of Lehigh Water-gap, i. 275—Lithological composition, i. 299—above Lockhaven, i. 551—McKean County, i. 300—in the north-eastern district, i. 299—northern limit, i. 306—organic remains, i. 300—Perry County. i. 363—Potter County, i. 300—thickness of the formation, i. 300—Savage Mountain, i. 574—north of Schuylkill Haven, i. 292—scenery, i. 287—in Warren County, i. 300—north-west of the Wyoming Basin, i. 305—sandstone, Broad Top region, i. 528—series, ii. 549, 756—physical geography of, ii. 793—in Shehola Valley, i. 304—strata, ii. 511, 517—in Armenia Mountain, ii. 142—Great Aughwick Valley, i. 427—thickness of, i. 141, 142.
Ponent and Verg. formations, Anthracite District, ii. 4.
Poplar Run, Pon. rocks, i. 559.
Porcupine, ii. 773—Run, ii. 517, 518.
Porphyritic rocks, i. 69.
Portage, i. 541—group, i. 756—railroad, i. 653—Cad. and Verg. rocks, i. 540, 541—Verg. rocks, i. 140, 141.
Port Alleghany, i. 548.
Port Carbon, dip of rocks, i. 37—section, Mill Creek, Faust Coal, ii. 139, 149.
Port Deposit, i. 49—gneiss rocks, i. 190.
Port Griffith, ii. 361, 373—8-ft. bed, ii. 366—Fives, ii. 362.
Port Kennedy, i. 675—boundary of Aur. limest., i. 180.
Port Royal, ii. 638.
Porter's Coal, ii. 565—bed, ii. 563—drift, ii. 564—mills, dips of the strata, ii. 573—quarry, Aur. limest., ii. 244—Run, ii. 537.
Posidonia, ii. 827.
Position of the State, i. 2.
Positions of the syn. belts of the Palæozoic strata, i. 98.
Post-meridian limest. in New York, New Jersey, and North-western States, i. 279—grits, i. 107—limest., i. 107—period, ii. 749—rocks, i. 113, 138—rocks north of Delaware Water-gap, i. 273—series, i. 755—series, physical geography of, ii. 791—slates, near Stroudsburg, i. 284—strata, thickness of, i. 138.
Potato Creek, ii. 487, 548, 550.
Potomac Basin, ii. 120—Cad. rocks, i. 139, 140—Cad. older black slate, i. 399—Cad. and Verg. rocks, i. 540, 541—Surgent rocks at Capon axis, i. 134—marble, i. 92, 204, ii. 684—Meridian rocks, i. 137, 138—sandstone, i. 399—Prem. limest., i. 136—River-basin, i. 40, 41—River, strata near Cumberland, i. 541—tabulated details, i. 45—Sca. grey marls, i. 398—limestone, thickness, i. 398—rocks, i. 135—Surg. rocks, i. 132, 133, 134—shales, thickness, i. 398—slates, i. 397—Verg. rocks, i. 140, 141—shales, i. 297.
Potsdam sandst., ii. 751, 780.
Potter County, i. 120, ii. 486, 487—Water-shed, i. 35.
Potter's Fort, dips of limst., i. 494.
Potts Gap, i. 371—Colliery, west of Pottsville, ii. 152—(G. H.) Slope, ii. 414—Mine, fault, ii. 105.
Pottsville, i. 146, ii. 23—anti. axis, ii. 35—basin, ii. 20, 77—thickness of Coal-measures, i. 113, ii. 6, 18—character of strata, ii. 235—view of, i. 25—coal-field, i. 114—measures, details, ii. 149, 150—group of rocks between the Pon. and Vesp., ii. 8—coal-basin, i. 118—temperature, i. 56—Ser. series, i. 146—Vesp. conglomerate, ii. 9—Vesp. rocks, i. 143.
Powell's Valley, i. 114.
Powderly Mines, ii. 332.
Powell Lands, ii. 249—shafts, ii. 255.
Prater's Ridge, Cad. slate, i. 426—Mer. sandst., i. 422—Prem. limest., i. 418.
Pre-meridian chert in middle division of Tuscarora Valley, i. 388—limestone, Bald Eagle Valley, i. 539—west of Buffalo Mountain, i. 571—Canoe Mountain, i. 556—fossils, i. 107—Dunning's Mountain, i. 557—west of Fruitstown. i. 453—iron ore, i. 410—on the Juniata, above Bell's Forge, i. 554—Kittatinny Mountain, i. 136—north of Lehigh Water-gap, i. 274—limit, i. 409—in Little Cove, i. 415, 419—between Muncy and Jersey Shore, i. 536—in Perry County, i. 346—on Pine Creek, i. 544—west of Dutotsburg, i. 283—period, ii. 749—rocks, i. 113, 114—Black Oak Ridge dip, i. 561—north of Delaware Water-gap, i. 272—Lewiston Valley, i. 399—Maryland Line, i. 567—and Sca. limests. south-west of McKee's Gap, i. 558—limestones in Whitedeer Hole Valley, i. 456—series, ii. 754—physical geography of, ii. 790—strata. south-west of Bloomsburg, i. 451—thickness of, i. 136.
Preston's, ii. 391—Coal, ii. 397—collieries, ii. 33—Main or North Gate, ii. 118.
Price's Colliery, ii. 420—opening, ii. 363.
Pricetown, ii. 716.
Priestley's Coal, ii. 374.
Primal altered slates, i. 152—conglomerate, i. 104—crystalline schists, i. 104—and gneissic strata, &c., near Spring Mill, i. 164—(Great Lower) group, west of the Schuylkill River, i. 157—iron ores, ii. 720, 721—lower slate on the Schuylkill, i. 122—newer slate, near Kemp's Inn, i. 200—older slate, i. 104—crystallisation, i. 158—near Maurer's Inn, i. 199—on Wissahickon Creek, i. 72—period, ii. 749—physical geography of, ii. 779—rocks, i. 113, ii. 4—anti. belts, i. 163—south of Attleborough, i. 152—Barren Hill, i. 161—south of Chester County Valley, i. 154—Chiques Ridge, i. 193—in Chester and Montgomery counties Valley, i. 111—Chestnut Hill, i. 242, 423—south of Creitz Creek, i. 184—exposures, i. 156—in the first or south-eastern district of the Palæozoic region, i. 111—near Gulf Creek, i. 168—from Jones's Mine to Pine Creek, i. 179—Mine Ridge, i. 176—near Neffsville, i. 179—Neversink Hill, i. 103—northern outcrop, i. 154—Parkesburg, i. 175, 176—west of the Schuylkill, i. 156, 185—in the South Mountains, i. 200—South Mountains, i. 112—southern trough, i. 151—S.E. of Stormstown, i. 501—Susquehanna River, i. 185—S.W. of the Susquehanna, i. 204—east of Valley Forge, composition. limits, i. 180—north of Walnut Town, i. 197—Welsh Mountain, i. 178—details of Willow Grove districts, i. 160—Willow Grove Turnpike, i. 160—York County, i. 192—sandst. bordering the Chester County Valley, i. 181—in Barren Hill, i. 162—Bucks and Montgomery counties, i. 151—Chiques Ridge, i. 194—between the Delaware and Schuylkill, i. 196—near Keeley's Old Stand, i. 200—Lehigh Hills, i. 97—south of the Little Lehigh, i. 197—east of Maurer's Inn, i. 199—south-east of Metztown, i. 197—on Schuylkill, i. 122—southern outcrop, i. 166—east of Springtown, i. 234—Pott's Forge, i. 200—slates in insulated tracts of limest., i. 226, 227, 228, 229—series, ii. 751—Chester County, i. 231—foot of Mount Sorrow, i. 180—in Peach Bottom, i. 189—injections of serpentine, i. 63, 169, 172—and Aur. limestone, i. 258—cleavage, i. 102—Montgomery, Chester, and Lancaster counties, i. 60—west of the Schuylkill, i. 156—series, southern belt, i. 150—strata, Adams County, i. 123—of Atlantic Slope, i. 149—Durham Hill, i. 99—from Marietta to Havre-de-Grace, i. 184—Mill Creek, i. 179—Montgomery, i. 160, 162—west of the Schuylkill, i. 153—near Spring Mill, i. 164, 165—syn. belt, i. 84—thicknesses of, i. 122, 123—its unconformity to the Gneiss, i. 99—west Nantmeal Township, i. 84—upper slate, in Barren Hill, i. 123—Chiques Ridge, i. 194—fossil, i. 104—white sandst., i. 152—fossils, i. 104—fourth belt of Aur. limest., i. 229—in insulated tracts of limest., i. 226, 227, 228, 229—in iron ore-bank of Chestnut Hill, i. 182—of Montgomery, Chester, and Lancaster counties, i. 60—North Valley Hill, i. 156, 173—white sandst., Welsh Mountains, i. 156.
Primary Appalachian Water-shed, i. 39—rocks, ancient definition, and later emendations, i. 62—water-shed, i. 40.
Primrose Coal, ii. 121, 130, 131, 142—East Norwegian, &c., ii. 217—Mill Creek, ii. 134—north of Wadesville, ii. 38—west of Saint Clair, ii. 87—Hill, ii. 154—anti. axis, ii. 152, 153—Seam, ii. 424—slopes, ii. 146, 423—Vein, anti. flexures, details, ii. 38.
Prince Edward Island, ii. 693.
Procamelus, ii. 773.
Productus, ii. 833—hirsutus, ii. 828.
Progress and types of life proved by foot-prints, ii. 832.
Progressive flattening of flexures, ii. 895—expansion of flexures, ii. 893.
Proportion of volatile matter in coal of Appalachian basins, ii. 808.
Prospect Hill, ii. 36—Academy Serpentine, i. 170.
Protomeryx, ii. 771.
Proved coal, ii. 59—vein, ii. 55.
Proving coal-seams, ii. 1009.
Psaronius, ii. 869.
Puddingstone at the base of Durham Hills, i. 100.
Pulpit Rocks, i. 50, 520.
Pumping-engine, ii. 445.
Punxutawney, ii. 484, 485, 586.
Pymatuning Ridge, iron ore, i. 585—Swamp, i. 39—Swamp, calcareous marl, i. 586.
Quaker Hill, ii. 557—Mer. sandst., i. 361—Mer. sandst., i. 354—Sca. and Prem. limest., i. 350—ridge of Surg. rocks, i. 342—Run, ii. 288—coals, ii. 288, 291.
Quantity of coal in different coal-fields, ii. 1017.
Quarries in the Aur. limest., i. 213—of blue porphyroidal gneiss, i. 79—of gneiss in first belt of Southern Zone, i. 70—of roofing-slate near Delaware Water-gap, i. 247—in the southern belt of Pri. sandst., i 153.
Quartz along the Tulpeboeken, i. 254.
Quartzose rocks, i. 72.
Queen's Run, ii. 481, 527.
Question of age, ii. 693.
Quick's coal, ii. 377.
Quiggle's Mill, Cad. black slates, &c., i. 551.
Quigley's Hollow, basin, ii. 31.
Rabbit-hole Coal, Oliver's Colliery, ii. 127, 139, 140—Bettinger's Mines, ii. 177—at Oliver's Colliery, Bear Ridge, ii. 221—Salem Colliery, ii. 175.
Racket Brook, ii. 331.
Racoon Creek, ii. 490, 569—Red-shale Valley, ii. 242.
Racoon Ridge, i. 528—Cad. grey sandst., i. 356—Cad. sandst., i. 337—Prem. limest., i. 346—structure, i. 357—third anti. axis in Post-mer. rocks, i. 314—Verg. shales, i. 357—Valley, belt of limest., i. 346—Surg. rocks, i. 314—Mer. sandst., i. 351—Surg. rocks, i. 337—railroad Iron-ore Bank, i. 268.
Rain at Carlisle, i. 56—Philadelphia, i. 56—at Philadelphia and Pittsburg, i. 56—averages for the year, i. 56—in Central States, i. 57—in first district, i. 5—at Fort Mifflin, i. 57—at Lambertsville, i. 57—of Pennsylvania, New Jersey, and East. New York, i. 56—at Carlisle, i. 57—at Pittsburg, i. 57—extreme quantities, i. 56—Gulf of Mexico, i. 56.
Rainbow Colliery, ii. 420.
Rainsburg, Aur. rocks, i. 508.
Ralston, ii. 512, 514, 515, 516—coal-field, ii. 482, 513—Pon. strata, i. 142—Old Mines, Seral series, i. 148—Umb. series, i. 145.
Ramsay's Run, ii. 511.
Ramyskill Cascade, i. 280.
Randolph Tunnel, Sharp Mountain, ii. 140.
Rankin's Clover Mill, i. 325.
Raphistoma staminea, ii. 817.
Rateliffe Mine, ii. 246—and Co.'s slope, ii. 99—new slope, ii. 245.
Rathfon Ore-banks, i. 218.
Rattlesnake Run. ii. 534.
Rattling Run Basin, Broad Mountain, ii. 224, 226—Gap, i. 490—coal strata, ii. 197.
Rau and Co.'s Boring, ii. 360.
Rausch Creek, ii. 182, 439—coal-beds, ii. 47—coal strata. ii. 165, 166—red-ash coal, ii. 184.
Rausch Gap, anti. axis, ii. 27—section, ii. 195.

Raven Coal-seam, ii. 415.
Ravensdale, ii. 32, 419—Hollow, sandstone and conglomerate, ii. 94—sandstone quarry, ii. 130—Tunnel, ii. 130—Primrose Coal, ii. 217.
Raven Slope, ii. 415.
Ravine Coal, ii. 111, 112.
Ravines in monoclinal strata, ii. 930.
Raystown branch of Juniata River, i. 50, 564.
Rebersburg, i. 484, 485—cavernous limestone, i. 492.
Red-ash coal, ii. 79, 147—Donaldson Basin, ii. 181—Middleport, ii. 115—Sharp Mountain Basin, ii. 37—Buckville, ii. 102—Coal Run Basin, ii. 305—Gate Ridge, ii. 37—Hoover's lands, ii. 387—Little Schuylkill, ii. 227—Little Schuylkill Valley, ii. 71—Measures, basin C D, ii. 87—basin F H, ii. 112—Mill Creek, ii. 230—Panther Creek Valley, ii. 67—Panther Creek Tunnel, ii. 75—Good Spring Creek, ii. 184—Little Lick Mountain, ii. 165—Silver Creek, ii. 228—Tamaqua, ii. 76—on West Branch and Wolf Creek, ii. 231—Cockle's Coal, ii. 173—Slope Coal, ii. 109.
Red Bank Creek, ii. 486, 492, 583, 585.
Red Hill, ii. 680—anti. flexure, i. 289.
Red Mountain, ii. 36—axis, ii. 166, 173—coal-bed, ii. 235—and Gate Ridge anti. axis, ii. 47—section of coal strata, ii. 184.
Red Ridge, ii. 305—anticlinal, ii. 286—coal-seams, ii. 293—tunnel, ii. 285, 286.
Red Run, ii. 514, 515—Ralston, ii. 470.
Red Shale Cove, anti. axis, ii. 269—Hollow, ii. 241—rocks, Swamp Creek, ii. 242—and sandst. in York and Adams, ii. 677—Valley of the Catawissa, ii. 248.
Redstone coal, ii. 505—bed section, ii. 625.
Redstone Creek, ii. 506, 612, 623, 624—section, ii. 644.
Reese Davis coals, ii. 430.
Reinhardt's Run, Coal E, ii. 79—details of coals, ii. 214, 215—dip of Coal D, ii. 78—property, ii. 101—tunnel, ii. 213.
Relative properties of coal, tabulated, ii. 1000.
Renfrewshire coal-field, ii. 984.
Rennie Coal, ii. 308.
Rennie's cottage, coals, ii. 314.
Repplier's Colliery, ii. 442—tunnel, ii. 273.
Reptiles of red sandst., ii. 695.
Reptilian footprints, ii. 833.
Requisites of good coal for steam, ii. 999.
Resumé of laws of structure, ii. 912, 916.
Revision of southern anthracite field, ii. 413.
Reynoldsville, ii. 544, 545.
Reynolds and Shunk's Furnace, ii. 585.
Rheno's Furnace, ii. 563.
Rhinoceros, ii. 771, 773.
Rhoad's Camp section, ii. 655—quarry, i. 153.
Rhume Run, anti. axis. ii. 50, 51, 54,—anticlinal, ii. 29—Mines, ii. 66—Ravine, ii. 54—28-feet coal-seam, ii. 56.
Rhynconella nobilis, ii. 825.
Ribbons in Mat. slate, i. 248.
Richardson's Colliery, ii. 442.
Richfield, Lev. rocks, i. 368—limest. belt, i. 383—Surg. rocks, i. 374.
Richmond coal-field, Cape Breton, ii. 951.
Riddle Mine, ii. 456.
Ridge Gate Coal, ii. 140—Ridge's Quarry, i. 153.
Ridge Turnpike, i. 73.
Ridgway, ii. 487.
Ridley Creek, i. 70, 168.
Rieff's Mill, i. 200.
Ripple-marks, ii. 831—Uhlersville, limest. quarry, i. 99—in Verg. flags, i. 296—in Verg. flags, Erie and Crawford Counties, i. 581.
Rising Mountain, i. 332—Lev. rocks, i. 315—Lev. strata, i. 340—Surg. slates, i. 339.
Ritter's Mine, ii. 724—ore-bank, ii. 723.
River-basins, i. 40—of the Atlántic system, i. 41—syn. axis, ii. 379—Wilkesbarre, ii. 380.
Rivers in First District, i. 4.
River-cliffs in First District, i. 5—Hill, iron ore, i. 218—scenery, First District, i. 5—of Pennsylvania, i. 47.
River system of the Alleghany River, i. 46—of the Delaware River, i. 43—of the Potomac River, i. 45—of the Susquehanna River, i. 44.
Roan Coal, Rohrer's Mines, ii. 203.
Roaring Brook, ii. 319—Basin, ii. 346, 348, 349—coals, ii. 338, 345—Falls, near Scranton, ii. 360.
Roaring Creek Valley, i. 115, ii. 11.
Roaring Run, i. 290.
Robbstown, ii. 637.
Robert's Creek, coal outcrops, ii. 263—shaft, ii. 262.
Rocher's Farm, band of limest., i. 251.
Rockland Town, ii. 571.
Rocks of mechanical origin, ii. 797—above the Pittsburg Coal, ii. 619, 623, 628, 640.
Rocktown, ii. 687.
Rocky Falls, i. 233—Ridge, ii. 450—Mer. sandsts., i. 515, 519, 522—Sca. limest., i. 517.
Rock Run, i. 84, 85—Pri. white sandst., i. 189—Hills, Pon. rocks, i. 548.
Rockland Township, belt of gneiss, i. 97.
Rocks embraced in Pennsylvania, i. 59—in Sixth District of Palæozoic region, i. 116—of the South Mountains, i. 95.
Rogers, Prof. W. B., discovers paradoxides in Eastern Massachusetts, ii. 816—on Mesozoic fossils, ii. 696—on origin of iron ores, ii. 737.
Rohrer's Colliery, ii. 447—mines, coal-beds, ii. 209.
Rohrersville Colliery, Peaked Mountain anti., ii. 210—coals, ii. 210.
Rolling Mill Dam, ii. 346.
Roof of the coal, ii. 803.
Root in Umb. sandst., ii. 830.
Ross Hill, ii. 407, 409.
Ross's Mines, Solomon's Gap, ii. 395.
Rosstown, ii. 688.
Roth's Mill to Pine Creek, gneiss rocks, i. 198.
Rotten coal, ii. 57.
Roudenbush Mine, ii. 716.
Rough coal, ii. 128.
Rough's Mill, ridge of Cad. black slate, i. 409.
Round Islands, ii. 483—knob section, ii. 459—top, ii. 454, 687, i. 249—anti., i. 332—anti. axis, i. 315—knob, Sur. iron sandst., i. 339—Surg. slates, i. 340—syn. knob, i. 332.
Rowland's Coal, ii. 58, 66.
Roxbury Bank, iron ore, i. 268—Lev. sandsts., i. 335.
Ruggle's Creek, ii. 384.
Run Gap, i. 330.
Rusophicus bilobatus, ii. 822.
Rutiodon, ii. 695.
Rye Township, Cad. and Verg. rocks, i. 359.
Saddles and basins, ii. 91.
Saddleback Ridge, i. 427.
Saddler's Limekilns, i. 350.
Safe Harbour Iron-ore Pits, i. 218—trap-rock, i. 186.
Saint Clair (South), anti. axis, ii. 32—(North) basin, ii. 31.
Saint Lawrence, lacustrine tracts, i. 38.
Saint Mary's, ii. 542, 552, 707.
Salem Coal, ii. 221.
Salem Colliery, ii. 175, 433—east of Pottsville, ii. 152—Red Mountain axis, ii. 173.
Salem group of coals, ii. 144—Hollow, Rabbit Hole Coal, ii. 221—section, ii. 151—slope mines, ii. 37.
Salisbury Basin, ii. 494, 505.
Salisbury section, ii. 499.
Salona, cellular ore, i. 499—pale blue sandst., i. 495.
Saltpetre Rocks, ii. 457.
Salt Well, Elk Lick Creek, ii. 651—Works, ii. 597.
Saltzburg, ii. 485, 502, 599—division of first basin, ii. 650—section at, ii. 601.
Sambo Creek, cascade, i. 280.
"Sand Chrome" in Serpentine Barrens, i. 171.
Sando's Coal, Dyer's Run, ii. 206—Colliery, ii. 206—Jugular Coal, ii. 217.
Sandrock Coal, ii. 125, 126, 129, 145, 162—west side of Mill Creek, ii. 219.
Sandrock group of coals, ii. 144—Slope, ii. 130.
Sandstones at Buck Ridge and Peaked Mountain, ii. 212.
Sandstone quarry, Ravensdale, ii. 130.
Sandy Creek Furnace, ii. 562—iron ore, i. 585.
Sandy Lake, ii. 562, 573.
Sandy Lick Run, ii. 484.
Sandy limest., Sugar Valley, i. 492—Ridge, i. 419, 423—Prem. limest., i. 352.
Sandy Run, ii. 461—Pri. rocks, i. 156—limest. quarry, i. 213—Mer. sandst., i. 419—Prem. limest., i. 419.
Sandy shales, i. 60.
Sarah Furnace, dip of strata, i. 558.
Saucon Creek, i. 101—belt of gneiss, i. 96—East Branch, i. 96—Mines, ii. 726—South Branch, gneissic ridge, i. 100, 101
Savage Mountain, ii. 504—Basin, ii. 505—Pon. rocks, i. 573, 574.
Sawkill, cascade, i. 280.
Sawmill, ii. 333.
Saxicava rugosa, ii. 775.
Scalent grey marls, i. 106—Kittatinny Mountain, i. 135.
Scalent limestone, Bald Eagle Valley, i. 539—Buffalo Valley, 459—Canoe Mountain, i. 556—Perry County, i. 346—fossils, i. 107—iron ore, i. 410—Kittatinny Mountain, i. 35—Lewistown Valley, i. 401—Mifflintown, i. 135—Montour Ridge, i. 451—Pine Creek, i. 544—south of Moon's House, i. 456—Stone Valley, i. 517.
Scalent marls, Dunning's Mountain, i. 557—and limest. along Blue Ridge, i. 413—Lewistown Valley, i. 398—Tuscarora Valley, i. 379.
Scalent period, ii. 749—rocks, Bald Eagle Mountain, i. 536—south of Bedford, i. 566—Little Scrub Ridge, i. 415—Maryland line, i. 567—near Millhall, i. 545—north of Lehigh Water-gap, i. 274.
Scalent and Prem. limestones, i. 383—Lewistown Valley, i. 416—Woodcock Valley, i. 522.
Scalent and Prem. rocks, i. 384—Pine Ridge, i. 558.
Scalent series, ii. 754—physical geography of, ii. 789.
Scalent strata from Muncy to Milesburg, i. 542—thicknesses of, i. 134, 136.
Scalent and Surg. strata, Buckstown Mountain, i. 561—variegated marls, fossils, i. 106—near Tuscarora Mountain, i. 135.
Scenery from the Alleghany Mountain, i. 34—of the anti. valleys, i. 30—from top of Blue Hill, i. 31—of broad valleys of complex structure, i. 31—Catawissa and Bloomsburg, i. 31—commanded by anti. mountains, i. 19—commanded by syn. coves, i. 17—Delaware River, i. 47—from the ends of the exterior coal-basins, i. 23—from the ends of the interior coal-basins, i. 24—of the Fifth District, i. 39—First District, i. 4—from Fox Hill, i. 32—of the Fourth District, details, i. 37—along the Juniata, i. 31, 32—along the Juniata River, i. 50—of Kittatinny Valley, i. 7—from Laurel Hill, i. 34—of mono. valleys, i. 31—in mountain-chain, i. 19—of mountain-crests, i. 25—in mountain-passes or notches, i. 28—between Pittston and Nanticoke, i. 31—from Red Hill, i. 32—of Second District, i. 6—from Shade Mountain, i. 20—along Susquehanna River, i. 48—details, i. 49—from syn. mountains, i. 22—of syn. valleys, i. 30—of Third District, i. 32—from Tuscarora Mountain, i. 20—in valleys of the Appalachian Zone, i. 30—valley of the Delaware, i. 32—from western spur of Welsh Mountain, i. 179.
Schell's Coal, ii. 452.
Schenck's Ferry, i. 217.
Schleppy's Farm, ii. 398—section at, ii. 400.
Schollenberger's Colliery, ii. 429—Glendower Colliery, ii. 446.
Schooley's Drift, ii. 363.
Schupp's Creek, ii. 407.
Schuyer's Limest. Quarry, French Creek, i. 232.
Schuylkill, Aur. magnesian limest., i. 124—Falls, porphyritic gneiss, i. 69—quarries of gneiss, i. 70—gneissic region, northward, i. 78, 79—Haven, anti. flexure, i. 289—Surg. red shale, i. 291—Mer. rocks, i. 278—middle district of southern coal-basin, ii. 84—micaceous and hornblendic gneiss, i. 71—Mountain, i. 290—Cad. and Verg. rocks, i. 292—Pri. white sandst., i. 150—pictorial section, i. 5—Prem. limest., i. 278—Pri. series, i. 122, 154, 155—below Reading, Pri. series, i. 123—River, i. 4—Basin, i. 41—gneissic belt, i. 70—limest. valley, i. 162—serpentine rock, i. 167—Valley, gneissic rocks, i. 67—gneiss near the bend, i. 74—northern belt, i. 94—and Swatara district, ii. 26—section through Summer Hill, i. 292—Umb. rocks, ii. 10.
Schwartz Knob, syn. ii. 460.
Sclough's Mine, ii. 724.
Scolithus linearis, i. 63, ii. 780, 815.
Scolopendrites, ii. 868.
Scott Tract, coals, ii. 289—and Hunter Tracts, ii. 307.
Scotch coal-fields, ii. 982.
Scotch Valley, i. 555.
Scranton, Seral series, i. 147, ii. 325—Basin, ii. 351—District, Coal-measures, ii. 338—coals of, ii. 329—lower Coal-measures of, ii. 354—iron ores, ii. 357—Roaring Brook, ii. 320—undulations of the strata, ii. 342.
Scrub Grass, ii. 490—Creek, ii. 573—coal-bed, ii. 491.
Scrub Ridge, i. 17, 115—Cad. and Verg. rocks, i. 394—Cad. and Verg. strata, i. 429—Surg. rocks, i. 382—Umb. limest., i. 530.
Scull's Hill, i. 253.
Scull's Run, ii. 571.
Searching for coal, ii. 1007.
Second basin, north-west of Alleghany Mountain, ii. 482—bituminous coal region, i. 120—traced to Cambria County, ii. 533—west to Pine Creek, ii. 511.
Second belt in the anthracite coal region, i. 118.
Second coal-basin, ii. 514—Ligonier Valley, ii. 497.
Second Mountain, i. 292—Pass, i. 29—Pon. and Vesp. rocks, i. 289—River Pass, pictorial sketch, i. 29—Susquehanna, i. 143—Vesp. rocks, i. 143.
Second subdivision of third coal-basin, ii. 628.
Second Twin Coals, ii. 79, 80—second zone, i. 66.
Section A, along the Delaware River, i. 98—of Appalachian chain, ii. 895—through Coatesville, &c., i. 174.
Seigler's Mine, ii. 725.
Seip's Tavern, diluvium, i. 96.
Selinsgrove, anti. axis, i. 372—near Selinsgrove, i. 138—Cad. and Verg. rocks, i. 391—Cad. older black slate, i. 399—Surg. marls, i. 374—Susquehanna, Cad. lower black slate, i. 138.
Selkirk or Oliver's Bear Ridge Tract, ii. 220.
Selkirk Coal, Salem Colliery, ii. 175.
Sellard's ore, ii. 517.
Semi-anthracite, ii. 993.
Semi-bituminous coals, ii. 990.
Seral conglomerate, i. 118, 577, ii. 49, 360, 412, 487, 496, 509, 554, 557, 567, 583—anthracite districts, ii. 21—Broad Top, ii. 449—character, i. 109—Coal Run Ridge, ii. 274, 275, 292—elevation at Tamaqua, ii. 106—general characters, ii. 16—Hertzoff's Hollow, i. 147—Locust Mountain, ii. 265—Mill Creek, ii. 201—Red Ridge, ii. 287—Scranton, ii. 338—Tamaqua, ii. 76—thicknesses of, i. 146, 148—Wyoming and Lackawanna coal-field, ii. 320.
Seral period, ii. 749.
Seral rocks, bituminous coal region, i. 119.
Seral sandst., ii. 546.
Seral series, ii. 758—at Mauch Chunk, i. 146—in Shamokin Gap, i. 147.
Serpentine Barrens, dykes of trap-rock, i. 169—belt, i. 189—near the Paoli Hotel, i. 168—Schuylkill, i. 167—near the State line, Lancaster, i. 171—Unionville Barrens, i. 170—Fourth Tract, i. 169—and hornblendic gneiss, John Gliceu's Farm, i. 168—Ridge, specimens of minerals, i. 172—strata, near the Susquehanna, i. 172.
Serrill's Lower Tunnel, details, ii. 171—Seven-feet Coal, ii. 171—Tunnels, Black Heath Coal, ii. 216—Black Valley Coal, ii. 217—Upper Tunnel, ii. 430—details, ii. 171.
Server's Coal, ii. 401.
Seven-feet Coal, ii. 363—at Lawton's Old Colliery Gap, ii. 202—Seam, ii 341, 366.
Seven-mile Narrows, i. 482.
Seven Mountains, i. 15, 483—anti. knobs, i. 453—character and dip of the strata, i. 486—knobs,

Lev. white sandst., i. 515—Mat. slates north of Thompson's Tavern, i. 480—range of the second and third ridges, i. 485—subordinate anti. flexures, i. 465.
Sewickley, ii. 606—coal, ii. 499, 505, 628, 630.
Sewickley Creek, ii. 501, 504, 604—section, ii. 618, 638, 640.
Seyler's Foundry, ii. 545.
Seymour coal-beds, ii. 336.
Shade Furnace, ii. 656.
Shade Gap, i. 371—ore sandst., i. 380.
Shade Mountain, i. 11, 12, 115, 362, 371, 377, 396—anticlinal, i. 115—anti. axes, i. 372—belt of limest., i. 383—curvature in the mountain, i. 403—details, i. 367—gaps in the south-east crest, i. 368—Millerstown, i. 345—south-east base, Mer. sandst., i. 388—round tops, i. 368—ridge of Cad. sandst., i. 394—south-east slope, Lev. sandsts., i. 372—scenery, i. 20—Surg. rocks, i. 374—Surg. slates and Sca. marls, i. 380.
Shades of Death, i. 287.
Shady Run, ii. 595.
Shæffer's Valley, i. 335—axes in the Surg. shales, i. 316—structure, &c., i. 342, 343.
Shafts at Pittston, ii. 372.
Shallowness of red sandst. of Atlantic Slope, ii. 814.
Shamokin Basin, i. 24—details of the coals, ii. 284—North Branch Coal-measures, ii. 292—red-ash coals, ii. 305—Basin, i. 17, ii. 6, 11. 17—boundaries, ii. 21—western end structure, ii. 308—anti. flexures, ii. 297—anti. axes, ii. 266, 307.
Shamokin Creek, i. 115—drainage, ii. 284—North Branch, ii. 280—range, ii. 280—South Branch, ii. 279.
Shamokin Gap. Coal-measures, ii. 299—exposures, ii. 289—Ser. series, i. 147.
Shamokin Mountain coal-beds, ii. 302—Coal-measures, ii. 292—dip of strata, ii. 309—at Shamokin Gap, ii. 299.
Shamokin Valley, i. 115.
Shank's Gap, Surg. ore sandst., i. 414, 418.
Sharon, ii. 560—calc. limest. and sandst., i. 584—coal group, ii. 489, 496—the Shenango, i. 578.
Sharp Mountain, ii. 33, 48—faults, ii. 234—faulty condition of the coal-beds, ii. 194—identification of the coal strata, ii. 151—position of the Summit Mines, ii. 64—Ser. conglomerate, ii. 22—syn. belt, lower red-ash coals, ii. 77—south of Patterson, ii. 113—view of, i. 25—anti. flexure, i. 289—and anti. C (basin), ii. 31—basin, coals in the north side, names and number of the beds, ii. 36, 151—syn. axis, ii. 37—white and red ash coal-beds, ii. 68—coal-beds at Rattling Run Gap, ii. 197, 186, 23—conglomerate, ii. 186—colliery, ii. 440—conglomerate dip, ii. 49—coals, ii. 81—section of the Coal-measures, ii. 149, 150—dip of coal strata, Tamaqua, ii. 76—dip of strata, ii. 26, 37.
Shaver's Creek, i. 513.
Shaver's Valley, Cad. and Verg. rocks, i. 569—Sca. marls, i. 517.
Shawangunk Mountain, i. 18, 47.
Shawnce Mountain, ii. 405.
Shehola Falls, Vesp. conglomerate, i. 304—Verg. and Pon. strata, i. 281.
Shenandoah axis, ii. 271, 273.
Shenango, i. 578—calcareous limest., i. 584—river, ii. 560.
Shenck's Ferry, Pri. rocks, i. 186.
Shepody Mountain and Bay, ii. 945.
Sherman's Creek, i. 341, 342—Mer. sandst., i. 354—Pon. red shale, i. 364—valley, 114—anti. axes, i. 314, 315—anti. axes in Cad. rocks, i. 356—anti. knobs, i. 332—average width, i. 313—Surg. slates and marls, i. 341.
Shickshinny Mountain, i. 23-25, ii. 9—Pon. rocks, i. 440—scenery, i. 48.
Shiffert's Inn, Pri. sandst., i. 198.
Shinersville, i. 96.
Shippensburg, i. 203, 206.
Shippenville, ii. 491, 571.
Shirleysburg, Cad. slate, i. 426.
Shocmaker's Mill, on Muncy Creek, Sca. marls, i. 536—ravine, ii. 406.
Short Mountain, i. 344, 493—Coal Co.'s mines, ii. 441—exposures of the strata, i. 505—North Terrace Ridge, i. 484—structure, i. 483—syn. axis, i. 550.
Short saddle D, coal-beds, ii. 108.
Shoup's Run, ii. 451, 453.
Shreeve's Run, ii. 459.
Shrewsbury station, i. 192.
Shumard, Dr, cited, ii. 968.
Shute's Run, ii. 624.
Sideling Creek Gap, Umb. limest., i. 530.
Sideling Hill, i. 50, 115, 116, 138, 142, 366, 528—anti. axes, i. 533—belt of Cad. and Verg. rocks, i. 428—Cad. lower black slate, i. 138—character and dip of the strata, i. 532—Pon. rocks, i. 521—Pon. strata, i. 142—Potomac Pon. red sandst., i. 400—dip of the Pon. strata, i. 429, 430.
Sidell's Tavern, limest. quarrics, i. 454.
Siegerville, ii. 723.
Sigillaria, ii. 871, 872, 873—flattened, ii. 317—with stigmaria roots, ii. 953.
Silkman Ravine, ii. 353.
Silliman and Meyer's slope, ii. 105, 414.
Sillimanville anti., details, ii. 32.
Silurian deposits, ii. 749—upper, ii. 785.
Silver Creek, ii. 417—anticlinal, ii. 32, 34—Big North Coal, ii. 216—Big or North Diamond Coal, ii. 87—coals, ii. 120—coal-beds, ii. 91—axis D, ii. 86—details, ii. 227—Colliery, ii. 418—Basin, ii. 31—comparison of the two sides of the synclinal, ii. 88—details of the coal strata, ii. 123—Peach Mountain syn. belt, ii. 93—reservoir, ii. 199—synonyms of the coals, ii. 222.
Silver Diggings, ii. 657.
Silver Glen, ii. 37.
Silver Hill, ii. 27—anti. axis, ii. 36—anticlinal, ii. 33.
Silver Hollow, ii. 109.
Silver Lake, i. 306.
"Silver Mine," ii. 679—Hill Lev. white sandst., i. 478—Knob, i. 522.
Silvertown Colliery, anti. axis, details, ii. 47.
Singley's Farm, details of the coals, ii. 137, 138.
Sink-holes, details, i. 518.
Sinking Creek, origin, sink-holes, i. 502.
Sinking Spring Gap, fragments of Mat. sandst., i. 480—trap-dyke, i. 251.
Sinking Valley, denudation, i. 502.
Sinnemahoning, i. 120, ii. 482, 484—Bennett's Branch, ii. 24—River, i. 49.
Sinnaminson Creek, gneissic rocks, dip, i. 79.
Sinnickson's slope axis, ii. 108.
Siveley's Coal, ii. 378.
Siverey and Longstreth Coal-seam, ii. 262.
Six-mile Run, ii. 455.
Sixteen-mile Creek, structure of the Verg. flags, i. 582.
Sixth Basin, ii. 489—details, i. 120—Freeport group, ii. 576—in Jefferson and Clarion counties, ii. 567—Mercer, ii. 564—in New York, ii. 547—north-western limits, ii. 558—north-west side, ii. 566—south-westward, ii. 553—west of Alleghany River, ii. 572—west of Beaver River, ii. 582—and final outcrop, ii. 488.
Sixth District, fifth belt, mono. structure, i. 117—first belt, i. 116—fourth belt, i. 117—second belt, i. 116—third belt, i. 116.
Sketch of Geology of the United States, ii. 741.
Skidmore Coal-bed, ii. 421—Casca William, ii. 217—Mine Hill Gap, ii. 169—lower white ash-group, ii. 18.
Slate Creek, ii. 511.
Slate Hill, i. 188.
Slate Point, cleavage-dip, i. 188—quarries, Kreidersville, i. 249—quarries, near Nazareth, i. 249.
Slatington, slate quarries, i 249.
Slenderdale Ridge, anti. axis, i. 368, 383—axis Cad. black slate, i. 392—axis, i. 372, 373—axis, Surg. rocks, i. 374—Surg. strata, i. 375.
Slide in River Hills, ii. 641.
Sligo Forge, Lev. sandst., i. 500.
Slippery Rock Creek, ii. 574.
Slopes, i. 39.
Slope Coal, ii. 111—Wolf Creek, ii. 171—mines, ii. 1012—of anti. valleys, i. 9—of syn. valleys, i. 9.
Small coal in Adam's Tunnel, ii. 204—quarry, gneissic rocks, i. 75.
Smethport, Pon. strata, i. 142, ii. 487, 489, 550, 554.
Smicksburg, ii. 486, 588.
Smith, Elisha's, Quarry, east of Gerard, i. 583.
Smythfield, ii. 660.
Smith's Gap, i. 288—quarry, near French Creek, i. 583—Tract coal-beds, ii. 342—Creek section, ii. 412—mine, ii. 408—sawmill, ii. 588.
Snake Creek, springs of salt water, i. 306.
Snake Spring Valley, details of the strata, i. 507, 508.
Sneyder's red-ash colliery, ii. 423.
Snow-shoe, ii. 481, 530.
Snyder and Milne's Lewis Coal Slope, ii. 138.
Soapstone Quarry, gneissic rocks dip, i. 79—steatite and serpentine, i. 167.
Soil of the north-west dist., i. 585.
Solomon's Creek, ii. 379—Gap. ii. 389—anticlinal, ii. 391—Coal, ii. 394—section, ii. 320—Ser. series, i. 147—Umb. series, i. 145—Vesp. rocks, i. 143, ii. 11—white-ash Coal-measures, ii. 328.
Solomon's Temple, i. 197.
Somerset, Umb. rocks, ii. 11.
Sorber's, ii. 385—House, ii. 388.
Sorrel Horse Inn, i. 160—Pri. sandst., i. 178.
Southampton Furnace, i. 268.
South Beaver Creek, details, ii. 248.
South Branch of Indian Run, gneissic rocks, i. 84.
South Branch of the Saucon, Aur. limest., i. 235.
South Clear Ridge, Pon. rocks, i. 521.
South Diamond, axis, ii. 38—Coal, ii. 121, 137—of Casca William, ii. 112. 218—synonyms, ii. 223.
Southern Coal-basin, i. 303—general classification of the Coal-measures of, ii. 224, 226—east of Middle Creek, ii. 179.
Southern limit of the drift, ii. 774.
Southern Middle Coal-field, Umb. red shale, ii. 12.
South Gate Coal, ii. 140—New Philadelphia, ii. 220.
South Horse Valley, i. 334—13th anti. axis, i. 316—Surg. rocks, i. 344.
South Mahanoy Basin, ii. 270.
South Mine Hill, anti., ii. 31—Big Coal of the south slope, ii. 86—white-ash Coal-measures, ii. 86.
South Mountain, i. 4, 47, ii. 2, 3, 715—belt, ii. 4—Aur. limest. between the Delaware and Schuylkill, details, i. 233—belt of Pri. and Aur. rocks, i. 112—Delaware River, i. 91—between the Delaware and the Schuylkill, i. 93—east of the Schuylkill, ii. 2—first belt of the second district, ii. 5—gneissic rocks, i. 91—Pri. rocks, details, i. 196—Pri. strata, i. 203—Schuylkill, i. 91—stratification, i. 98—south-west of the Susquehanna, origin, i. 203—undulations in the chain, i. 94.
South Nittany Mountain, i. 484.
South Valley Hill, micaceous slate, i. 169—east of Morgan's Corner, i. 168—Pri. sandst., i. 166.
South Salem Coal, Salem Colliery, ii. 176.
South Scranton, exposures of coals, ii. 346.
Spangler and Eckle's Mines, ii. 164.
Spangler's Four-feet Coal, ii. 183.
Spang's Furnace, i. 200—Pri. white sandst., i. 98.
Spanish Hill, near Athens in Tioga County, i. 37.
Spearing's Tavern, ii. 368.
Spencer's coal-mine, ii. 338—Wolf Creek, ii. 172—east of Wolf Creek, ii. 159—coals, ii. 345.
Sphenophyllum, ii. 852, 853.
Sphenopteris, ii. 861, 862.
Spie's Church, Sandstone Ridge, i. 198.
Spier Bed, ii. 461.
Spirifer, ii. 833—arenosa, ii. 826—mucronata, ii. 828—spiriferoides, ii. 828—sulcatis, ii. 825.
Spitzberg, i. 249.
Splint coal, ii. 995.
Spohn Coal, ii. 129, 130, 148, 416, 436—air-shaft, ii. 121—Bed, ii. 125—Branchdale Colliery, ii. 176—at Middleport, &c., details, ii. 219—Tremont, ii. 439, 145—details, ii. 95—of Muddy Branch anti., ii. 160, 161—outcrop basin, ii. 35.
Spring Brook, ii. 324, 364—towards Scranton, ii. 356—white-ash Coal-measures, ii. 328.
Spring Creek, Cad. black slate, i. 456—cement layers, i. 498.
Spring coal, ii. 111, 112.
Springfield, i. 85—Furnace, i. 506.
Spring Mill, exposure of Pri. rocks, i. 155, 156—gneiss, i. 77.
Spring Mill, limest. quarries, i. 213—marble quarries, i. 215—older Prim. rocks, i. 68.
Springtown, dip of limest., i. 234.
Spruce Creek, search for coal, limest. rocks, i. 500, 501—Run, limest., i. 502.
Spurs of Tussey's Mountain, anti. axes, i. 514.
Squire Winter's Mine, ii. 375.
Stafford Meadow Brook, ii. 318—anti. axis, ii. 342—Umbral strata, position of iron ore, ii. 357.
Stafford Meadow Valley, calc. iron ore, ii. 320.
Staffordshire Coal-field, ii. 978.
Stahl (Adam) Coal, anti., ii. 111.
Standerfer's Knob, i. 522—Lev. white sandst., i. 478.
"Standing Stone" Valley, i. 512.
State line, i. 119—mine, i. 171—serpentine belt, i. 192.
Statistics of coal trade, ii. 1019.
Statistics of iron trade, ii. 1020.
Staunton's Tunnel, ii. 209.
St Clair Colliery, ii. 422.
Steatite range of the Schuylkill, i. 167—and serpentine belt, i. 71.
Steele's iron-ore pits, ii. 707.
Steel-iron pits, i. 85.
Steffy's Tavern, Surg. slates, i. 513.
Steinberger's Basin, ii. 33—Mine, ii. 115.
Steitler Ore-bank, ii. 89.
Stems, ii. 868—of trees in coal str., ii. 846.
Sterret's Gap, i. 350—Merid. sandst., i. 354.
Sterrett's Mill, streams in limest. str., i 476.
Steven's and Paxton's Furnace, conglomerate, i. 205.
Stevenson Coal, ii 138.
Stewart's Furnace, ii. 499, 665.
Stewart's Knob, i. 403.
Stigmaria, ii. 869, 870—fucoides, ii. 802—root of Sigillaria, ii. 803.
Still House Coal, ii. 377.
Stiver's Bed, ii. 390—Bed, ii. 402.
Stockholm, ii. 546.
Stockton, Hazleton coal-basin, details, ii. 259.
Stone Church, Sca. and Prem. limest., i. 347.
Stone Creek Knob, anti. axis, i. 513—Ridge, Verg. and Pon. rocks, i. 521—outcrop of limest. rocks, sink-holes, i. 518.
Stone Mountain, i. 116, 482—Fault, i. 513—iron ores, i. 479—Lev. grey sandst., i. 472—Lev. white sandst., dip of the strata, i. 515—line of fault, i. 477—debris of Mat. sandst., i. 480.
Stone Ridge, details of rocks exposed, i. 274—Lehigh Water-gap, Mer. sandst., i. 288.
Stone Slides, i. 27.
Stone Valley, i. 482—ore sandst., i. 401—syn. flexure, i. 512—Verg. flags and Pon. red shales, i. 520.
Stony Creek, i. 33—section at, ii. 654, 655.
Stony Fork, ii. 523.
Stony Ridge, Nanticoke Mountain, ii. 404—ore-hill, i. 516—Surg. shales, i. 514.
Stony Run, ii. 514.
Stout's (limestone) Quarry, i. 233.
Stoystown, ii. 494—Basin, ii. 495.
Strasburg, belt of Aur. limest., i. 261—Lev. sandst., i. 335, 336—Surg. slates, i. 345.
Strata elevated by anticlinals, ii. 362, 370—in immediate contact with coal-seams, ii. 802.
Stratification from a state of suspension, ii. 813—of the South Mountains, i. 98—without suspension, ii. 812—by water in motion, ii. 812—arrangement of Coal-measures, Western Pennsylvania, ii. 474.
Stowable capacity of coals, ii. 1001.
Strattonville, ii. 569.
Street Road Basin, Aur. limest., i. 229—Prim. white sandst., i. 229.
Street Road Limestone Basin, metamorphism, i. 228.
Striated floor of the Drift, ii. 774.

Strickler's Run, Aur. str., i. 221—Prim. newer slate, i. 220.
Strictopora acuta, ii. 818.
Strinestown, ii. 678.
Strode's Mill, outcrop of serpentine, i. 170.
Strong's Turnpike Gate, i. 578.
Strontia, i. 215.
Strophomena Chemungensis, ii. 829—crenistria, ii. 827—demissa, ii. 827—punctulifera, ii. 825.
Stroudsburg, Post-mer. limest., i. 282—across Walpack axis, i. 285.
Stroud's Mill, Surg. fossiliferous ore, i. 432.
Structure of disturbed zones, ii. 885—Gneiss District, north of Chester County Valley, i. 85—the mountain-crests, i. 25—Second District, i. 5—South Mountains, i. 94—syn. belts of the Palæozoic strata, i. 98—Third District, i. 32.
Stuchel's Coal, ii. 589.
Subsidence of land in coal period, ii. 807.
Sugar Creek, Verg. rocks, i. 310, ii. 386, 391, 483—Lake, ii. 559—section, ii. 577.
Sugar-Loaf Knob, Seral conglomerate, ii. 243—Mine, 256—Slope, ii. 258.
Sugar Valley, i. 9, 50, 116, 418, 489—anticlinal, i. 484, 485—anti. axis, i. 487—anti. axis, i. 466—Aur. limest., i. 491—to Nittany Valley, i. 488.
Sulphate of baryta, i. 258.
Sulphuret of copper, near Duncan's Point, i. 187.
Sulphur Spring Gap, i. 511, 571.
Summer Hill, i. 290, ii. 653.
Summit Basin, daily product of coal, ii. 74—Hill, anticlinal, ii. 52—basin B, C, red-ash coals. ii. 71—cost of lifting the coal from Panther Creek, ii. 74—Great Coal bed. ii. 63—mines, ii. 65—red-ash coals, ii. 71—and Tamaqua anticlinal, ii. 29.
Summit Mine, ii. 65—Basin and Dry Hollow Ridge, ii. 30—of the Lehigh Company, ii. 63, 67—white, grey, and red ash coals, ii. 69.
Summit Pennsylvania Railroad, ii. 652.
Sunbury Railroad, coals, ii. 300.
Sun-cracks in Umb. red shale, ii. 831.
Surface-shafting for coal, ii. 1008.
Surgent fossiliferous iron-ore, ii. 359—iron sandst., i. 106—Fishing Creek, i. 447—Lehigh Water-gap, i. 132—near Shade Mountain, i. 371—Will's Creek axis, i. 132.
Surgent lower ore-shale, i. 106.
Surgent lower slate, Delaware Water-gap, i. 131—Fishing Creek, i. 447—fossils, i. 106.
Surgent lower shale, Perry County, i. 133—lower and upper ore-shales, near Jersey Shore, i. 537.
Surgent ore-sandst., i. 106—at Lehigh Water-gap, i. 133—shales, Lewistown Valley, i. 398—Stone Mountain, i. 515—period, ii. 749.
Surgent red marl, i. 106.
Surgent red shale in Dunning's Mountain, i. 557—Dutotsburg, i. 283—marl, Lehigh Water-gap, i. 134.
Surgent rocks, i. 113, 114—Bald Eagle Mountain, i. 536—Bald Eagle Brush Mountain, i. 554—north of Delaware Water-gap, i. 272—iron ore, i. 410—north of Lehigh Water-gap, i. 274—Lewistown Valley, i. 397—from Lewistown to Maryland, i. 412—at the Maryland line, i. 567—west of Mifflinsburg, i. 458—near Millhall, i. 545—Montour Ridge, i. 436, 437—in Perry and Franklin counties, i. 336—Pfout's Valley, i. 337—east of Jersey Shore, i. 543—Stone Valley, Surg. fossiliferous ore, i. 515—Susquebanna Gap, i. 276—Whitedeer Hole Valley, i. 455.
Surgent and Scalent rocks, i. 329, 381.
Surgent Series, ii. 753—physical geography of, ii. 788.
Surgent shales, north-east of the Juniata, i. 515—and marls, Juniata, above Bell's Forge, i. 554—Woodcock Valley, i. 522.
Surgent slate, west of Adamsburg, i. 401—and shales in the Seven Mountains, i. 481—Tuscarora Valley, i. 379—south-west of Waterloo, i. 381.
Surgent strata, i. 377—east of the Juniata, i. 374—Little Scrub Ridge, i. 415—near Danville, i. 435—from Muncy to Milesburg, i. 542—thicknesses of, i. 131, 132, 133, 134.
Surgent upper ore-shale, fossils, i. 106.
Surgent upper shale, Lehigh Water-gap, i. 133.
Surgent upper slate, fossils, i. 106—Lehigh Water-gap, i. 132.
Susan-Ann Furnace, iron ore. i. 192—coal-bed, ii. 430.
Susquehanna, i. 114—anti. flexures, ii. 4—a gap in Kittatinny Mountain, i. 276—Cad. rocks, ii. 138, 139—Cad. sandst., i. 293—Lev. grey and white sandst., i. 127, 130—Narrows, i. 310—North Branch, i. 119—Verg. flags, i. 295—Verg. rocks, i. 453—Verg. shales, i. 297—Pon. strata, i. 141—River, i. 4, 44, ii. 527—anti. axis, i. 372—Basin, i. 40, 41—Pass, i. 29—cleavage planes, i. 184—Pri. rocks, i. 186—scenery, i. 48, 49—Valley scenery, i. 37—West Branch, i. 49.
Susquehanna, Surg. iron sandst., i. 277—Surg. red shale, i. 293—Verg. flags, i. 541—Vesp. conglomerate, i. 301—Vesp. strata, ii. 8—Water-gap, Cad. black slate, i. 362.
Sutton and Wright's Tunnel, ii, 429.
Swallow's House, ii. 375.
Swallow, Professor, defines Missouri coal-field, ii. 965—researches cited, ii. 787.
Swamp Axis of West-West Branch, ii. 44—Creek, anti. valley, ii. 242—limest. quarries, i. 201.
Swartz iron ore, north of Jersey Shore, i. 550.
Swartzel's Valley, anti. axis, i. 463—flexures of strata, 475, 476—limest. quarry, dolomite layers, i. 476
Swatara, ii. 163—colliery, ii. 436—coal-field, i. 316—Creek, Aur. limest., i. 251—grey-ash and red-ash coals, ii. 156—details of coals, ii. 177—Falls, anti., ii. 152, 156—axis, ii. 41—Black Valley Coal, ii. 217—Gap, Cad. sandst., i. 293—limest. ridge, i. 291—Premer. limest., changes of type, i. 278—red-ash coals, ii. 166—Seral conglomerate, ii. 153—Valley, coal-beds, ii. 47.
Swetland Meadows, outcrops of coals, ii. 352—Mine, ii. 344.
Swift Creek, grey-ash coal, ii. 106.
Swigert's Gap, Cad. rocks, i. 571.
Switchback, anti. axis, ii. 32—Casca William Railroad, ii. 111.
Swope Hill, Cad. rock, i. 292, 293.
Sydney County coal-field, ii. 950—Knob, i. 326—Lev. white sandst., i. 382.
Syenite, i. 69.
Syenite and granite, i. 75.
Synclinal axis on Kishacoquillas Creek, i. 407—in Mat. slate belt, i. 261—planes dislocated, ii. 898—in Perry and Franklin Counties, i. 338—near Tamaqua, ii. 77—of third belt, Sixth District, i. 462—of basin B, ii. 80—Cad. and Verg. rocks, i. 361—D, ii. 80—south-east of Elliotsburgh, i. 353.
Synclinal basins, Vesp. sandst., ii. 5—belts, eastern middle coal-field, ii. 239—how eroded, ii. 924, 927—Fifth District of the Palæozoic region, i. 114, 115—coves in Union County, i. 17—crests, i. 26—flexures or basins, ii. 29—Fifth District of Palæozoic region, i. 114, 115—western middle coal-field, ii. 266—Sixth District of Palæozoic region, i. 116, 117—South Mountains, i. 94—ridge, Franklin County, i. 26—ridges and plateaus, i. 12—valleys, i. 10—spurs, i. 13—trough of Pon. rocks, i. 289—troughs, Lewistown Valley, i. 403—Mer. sandst., i. 422—Sca. and Prem. limest., i. 418—western middle coal-field, ii. 290—Valley of Montgomery and Chester counties, Pri. strata, i. 158—valleys, i. 15, 527—scenery, i. 30—structure, examples, i. 17.
Synonyms of the coals of the Pottsville Basin, ii. 221.
Syrigodendron, ii. 873.
Tables of Analyses, iron ores, ii. 717, 721, 727, 728, 731, 732, 733, 734.
Table of chemical constitution of coals, ii. 969, 976.
Table of coal produce, ii. 987.
Table of relative economic rank of coals, ii. 1000.
Table of Contents, i. ix. vol. ii.
Tabular arrangement of Bituminous Coal-measures, ii. 477.
Tafton, bog iron-ore, i. 304.
Tamaqua, anti. axes, ii. 77—Coal A, ii. 100—beds, syn. axis, ii. 76—C, ii. 101—E, ii. 104—F, ii. 68—synonyms, ii. 221—Gap, Coal C, ii. 78—individual coal-seams, ii. 77—Middle and Newkirk, anti. axis, ii. 30—and Newkirk Basin, details, ii. 30—Section, white-ash coals, ii. 70—Ser. series, i. 146—to Silver Creek, ii. 114—Southern and Eastern Mine Hill, ii. 30—Turnpike, coals, ii. 247.
Tangascootac, ii. 24, 528, 529—Creek, ii. 481.
Taylor's Colliery, ii. 446—Ford, i. 82—hornblendic gneiss, i. 78—Run, Aur. rocks, i. 231—hornblendic gneiss, i. 78—serpentine, i. 169.
Taylorsville Shaft Mines, i. 346.
Taylor and Volpert's Colliery, ii. 445.
Tea Spring, Solidago or Golden Rod, i. 492.
Tellina Greenlandica, ii. 775.
Temperature, autumn mean, i. 54—average of the year, i. 53—extremes of, i. 54—mean maximum, i. 54—of the northern border of the State, i. 53—of the southern border, i. 53—spring mean, i. 53—summary, i. 54—summer mean, i. 53—tabular statement during sixty years, i. 55—winter mean, i. 54.
Ten-feet coal, Thick Mountain, ii. 181.
Tentaculites ornatus, ii. 824.
Terrace Knob, i. 512—Mountain, i. 50, 484, 527, 528—Pon. rocks, i. 521.
Terraces, how eroded, ii. 931.
Tertiary formations. ii. 767—strata, ii. 768.
Testudo Nebrasensis, ii. 771—Niobrensis, ii. 773.
Thecodon saurians, ii. 695—saurian tooth, ii. 693.
Theories of cleavage reviewed, ii. 909—of flexure of strata, ii. 906, 907.
Theory of coal, ii. 806—of origin of coal, ii. 805—of undulation of strata, ii. 911.
Thick Mountain, ii. 154—Tunnel and Drifts, ii. 181—sandst. measures, ii. 155.
Thickness of ancient deposits, i. 60—of coal, ii. 484—of Palæozoic strata, i. 122-148—of limest. overlying Pittsburg Coal, ii. 798.
Third Basin in bituminous coal region, i. 120.
Third Basin, ii. 483, 499—along Conemaugh, ii. 599—in Indiana County, ii. 589, 590—south of Conemaugh, ii. 616—traced into Indiana County, ii. 538—west to Pine Creek, ii. 519.
Third Belt in the Anthracite coal region, i. 118—Coal-basin, Conemaugh, ii. 602—District, i. 32—and Fourth Basins, ii. 586, 588.
Third subdivision of Third Basin, ii. 636—zone, boundaries, i. 66.
Thirty-nine Feet Coal, details, ii. 58.
Thomaston Colliery, ii. 445.
Thomastown Tunnel, Mine Hill, ii. 207.
Thompson's Run, Section, i. 572.
Thompsontown, Cad. rocks, i. 392—Surg. slates and Sca. marls, i. 380.
Thompson Bed Forge Creek, ii. 400.
Thomson, Turner, and Co's Well, ii. 605.
Thom's Run, anti. axis, i. 550.
Thornhill Run, ii. 457.
Thorpe's Mill, serpentine rock, i. 167—paper-mill, Wissahickon Creek, i. 72.
Three-corner Pond, Post-mer. anti. belt, i. 452.
Three-feet Vein at the West Branch, ii. 170.
Three Spring Creek, iron ore, i. 522—junction with Aughwick Creek, i. 428, 429.
Three Springs, Cad. and Verg. strata, i. 427—Sca. and Prem. limest., i. 417—Surg. rocks, i. 412.
Three-square Hollow, i. 335, 342.
Thunderstruck Rock, ii. 458.
Tidiente, ii. 557—Creek, ii. 489.
Tinklepaugh Coal Company, ii. 336—Creek, ii. 333.
Tioga, or Chemung River, ii. 487—Colliery, ii. 413—County, i. 120—Verg. rocks, i. 140, 141—Verg. shales, i. 297.
Tioga Point, anti. axis, i. 306, ii. 483.
Tioga River, ii. 484, 519, strata east of the river, i. 310—Umb. series, i. 145—Pon. strata, i. 142.
Tionesta, i. 120—Coal, ii. 561, 562, 566, 570, 583—Bed, ii. 563—Group, ii. 488, 489, 496, 558.
Titaniferous iron-ores, i. 171.
Titanotherium, ii. 771.
Toby Creek, ii. 406.
Toger's Limestone Quarry, i. 235.
Tollgate Ridge, i. 408.
Tomb's Run, ii. 511.
Tome's Creek, ii. 518.
Tomhicken Basin, coals, ii. 256—Creek, ii. 241—Ridge anti., details, ii. 255.
Top slate, ii. 317.
Torbane Hill coal, ii. 995.
Tott's Gap Road, limest. quarry, i. 246.
Toughcanem Hill, limest. trough, i. 226.
Towanda, i. 120—anti., i. 295, 205—basin, ii. 513—coal-basin, ii. 513—field, ii. 482—Creek, ii. 482, 512—anti. axis, i. 308—coal-basin, ii. 15—limest. quarries, i. 309—Pon. str., i. 142—valley, i. 309—Mountain, ii. 482—Township Road Bridge. i. 200.
Tracey Coals, ii. 134—conglomerate and slate, ii. 94.
Trails of mollusc, ii. 832.
Trap adjoining iron-ore Cornwall Mine, i. 87—dykes, ii. 671, 691—in Aur. limest. west of Reading, i. 251—Bethel Hill, i. 165—near Conshohocken, i. 214—Conewango Falls, i. 49—Cove Mountain, i. 366—east of Churchtown, i. 221—hornblendic, i. 75—in railroad cutting, ii. 691.
Trap-dykes west of Lancaster, i. 222—of Mesozoic belt, ii. 684—near Millerstown, i. 222—of minerals, ii. 671—near Springfield township, i. 214—in southern zone of gneiss, i. 70—west of the Susquehanna, ii. 688—and their effects on the str., ii. 686, 688, 690—Warwick Iron-mine, ii. 687—of the Wheatley Lode, ii. 702—in Wheatley Mine, ii. 702, 703—Yellow Breeches Creek, i. 266—near York Springs, ii. 689—rock, i. 169—in gneissic rocks, i. 78—west of the Little Elk, i. 170—near Lockport, i. 186—ridges near New Hope, i. 48.
Trap-rocks of Mesozoic, ii. 763—near the Schuylkill, ii. 686.
Trask, Dr, researches, ii. 773.
Traveller's Rest, ii. 392.
Travertin, Antietam Creek, i. 259—bed at Wellsborough, i. 312.
Tredyffrin Township, Pri. white sandst., i. 173.
Trembleville, hornblendic gneiss, i. 78.
Tremolite, i. 95.
Tremont, ii. 439—anti. R. ii. 164—basin, ii. 47—flexure, identity with axis of Swatara Creek, ii. 165—Gap, faulty condition of coal, ii. 185.
Trenton limest., ii. 752—fossils, ii. 818—Pri. white sandst., i. 150—scenery, i. 48.
Tresckow anti. axis, ii. 247.
Trevorton Coals, ii. 313, 314—coal-field, ii. 315—Twin Coal, ii. 304—district of Shamokin coal-field, ii. 309—or Zerbe's Gap coal-field, ii. 316.
Trexell's Ore-mine, ii. 723.
Trexler's Furnace, i. 266.
Trexlerstown, flexures, i. 241—iron mines, 725—iron ores, i. 264—iron-ore mines, i. 265.
Trigonocarpum, ii. 877.
Trilobites, ii. 824.
Trinucleus concentricus, ii. 820.
Tropodileptus, ii. 827—carinatus, ii. 828.
"Trouble" in a coal-seam, ii. 238.
Trough Creek Gap, ii. 450—anti. flexure, i. 523—str., i. 528—Furnace, i. 529—Valley, i. 522—iron ores, Umb. limest., i. 529, 530—syn. axis, i. 532—Umb series, i. 145—Spring Hollow, ii. 457.
Troup's Creek, Verg. red shale, i. 312.
Trout Run, i. 120, ii. 484.
Troy, ii. 584—Gap, Ser. series, i. 148.
Tubmill Harbour, i. 527.
Tucker's Big Coal, ii. 121—Mine, Grier Vein, ii. 106—Slope, ii. 104—Coals, ii. 215, 216—Slope, Grier Coal east of Tuscarora, ii. 103.
Tulpehocken Creek, Mat. slate, i. 250.
Tumbling Coal, M'Ginnis's Hollow, ii. 205, 206—Mecke's Western Tunnel, ii. 208—Pine-knot Colliery, ii. 204.
Tunamaguont, ii. 553, 555—Settlement, ii. 548—Creek, ii. 549.
Tuniangwant, ii. 489.
Tunkhannock Creek, ii. 508—Vesp. rocks, i. 306—

Hills, Pon. and Vesp. rocks, i. 305—Pon. str., i. 142.
Tunnel or Back Coal, ii. 130—Peaked Mountain, ii. 208—coals, ii. 139, 140—coal, ii. 173—Oliver's Colliery, ii. 127—Oliver's Slope, Bear Ridge, &c., ii. 220—Salem Colliery, ii. 175—vein, ii. 117—Bettinger's Mines, ii. 177.
Tunnels, ii. 29—in coal-mines, ii. 10, 11—in Lawton's Old Colliery, ii. 202—in Nesquehoning Mines, ii. 55.
Turkey Foot, ii. 659—Hill, i. 49—cleavage, i. 192—Pri. rocks, i. 185—Ridge, i. 337—Cad. and Verg. rocks, i. 385—Cad. rocks, i. 392.
Turkey Valley, i. 392.
Turtle Creek, ii. 636—and Oreodon Bed, ii. 772—Run Valley, anti. axis, i. 462.
Tuscarora, ii. 26, 413—axis, i. 136—Prem. limest., i. 136—Mer. slate, i. 137—and Big Creek Colliery (Basin), details, ii. 31—to Casca William, synonyms of the coals, ii. 224—Church Saddle, details, ii. 30—coal, details, ii. 103—coal of, ii. 216—Creek Valley, i. 17—Verg. and Cad. rocks, i. 115—coals, ii., 214, 215—to East Norwegian, anti. axis and syn. troughs, ii. 92—Mountain, i. 262, 378—anti., i. 114, 337—anti. axis, i. 345, 372, 373, 393, 394—north-west flank, anti. axis, i. 381—Lev. sandsts., i. 330—Mat. slates, i. 314—Mat. slate, i. 322—Sca. grey marls, i. 329—Sca. rocks, i. 135—scenery, i. 20, 51—saddles, red-ash and grey-ash coals, condition of the str., ii. 108—Valley, i. 377—Cad. and Verg. rocks, i. 385, 393—divisions, i. 378, 379—geological structure, i. 372, 379—south-east division, i. 381—and vicinity, synonyms of coals, ii. 222—village, ii. 30.
Tussey Mountain, i. 15, 50, 116, 117, 482, 483—anti. axes, i. 514—anti. flexures, i. 523—anti. axes of the spurs, i. 514—Terrace, Aur. and Mat. rocks, i. 504—dips of str., i. 507, 508—Lev. white sandst. and Surg. shales, i. 515—Terrace, Lev. grey sandst., i. 500.
Tuttle's Coal, ii. 356.
Twelve-feet Coal, details, ii. 59.
Twenty-eight Feet Coal-seam, ii. 51.
Two Lick Creek, ii. 590.
Two Log Run, i. 84.
Two Top Mountain, i. 262.
Tyler and Agard's Slope, ii. 125.
Types of Palæozoic str., i. 122-148.
Type and thickness, Umb., ii. 469—of Vesp. sandst., ii. 467.
Tyrone Gap, i. 502—Lev. sandst., i. 553—Surg. ore limest., i. 553—Township, Cad. and Verg. rocks, i. 359.
Uhlersville limest. quarry, i. 233.
Ulodendron, ii. 875.
Umbral, Chestnut Hill Gap, ii. 472—details of, ii. 469—formation, ii. 487—near Scranton, ii. 319—footprints, ii. 831—limest., ii. 472, i. 108—Trough Creek Valley, i. 530—Little Trough Creek, i. 530—Youghiogheny, ii. 473—modifications in type, &c., ii. 469—ore, ii. 609—ore-bands, ii. 613—period, ii. 749—red shale, i. 118, ii. 22, 49, 239, 240, 274, 318. 468, 496, 498, 508, 509, 510, 517, 526—Big Scrub Ridge, i. 431—Broad Mountain, ii. 153—character, i. 108—composition, &c., ii. 9, 10—geographical range, ii. 11—Hunter's Valley, i. 365, ii. 12, 514—Red Ridge, ii. 287—south of Gladding's Run, i, 575—Trough Creek Valley, i. 531, 532.
Umbral rocks, ii. 358—anthracite country, ii. 7—bituminous coal region, i. 119—Mauch Chunk, i. 144—Tamaqua, ii. 76—series, i. 466, 757—physical geography of, ii. 794—shale, ii. 451, 483, 485—Ray's Mill, ii. 603—str., Conemaugh Gap, ii. 471—thicknesses of, i. 144, 146.
Unconformable continuous sequence, ii. 778—interrupted sequence, ii. 778.
Unconformity of Prem. upon Mat., ii. 785—of the Pri. strata to the gneiss, i. 99.
Underclay of coal-beds, ii. 802.
Undulations, ii. 325, 327—of the basin, ii. 324—of crust-parallel, ii. 886—of Illinois coal-fields, ii. 963—in Sca. strata shown, ii. 894.
Undulated zones of Europe, ii. 899, 902.
Union Furnace, ii. 503—(Old) Furnace, ii. 612—slate quarry, near Lehigh Water-gap, i. 248.
Uniontown Coal, ii. 505, 506, 618—bed, ii. 620—Prem., Mer., and Cad. rocks, i. 455—section, ii. 624—small double coal, ii. 628.
Unionville, ii. 577—limest., quarries, i. 229—serpentine belt, i. 170.
Upper coal-beds, ii. 412—measures, ii. 759.
Upper Delaware plateau, i. 47.
Upper Diamond Coal, ii. 131—outcrops, ii. 32.
Upper Freeport Coal, ii. 19.
Upper Helderberg Limest., ii. 755.
Upper lakes, lacustrine tracts, i. 38.
Upper Merrion Towuship, Aur. limest. quarries, i. 213, 214—marble quarries, i. 215.
Upper Panther Creek Basin, details, ii. 29.
Upper red-ash coals, ii. 79, 80.
Uwchlan Township iron-ore, i. 90—pipe-clay, i. 87—Primal rocks, i. 151—Aur. limest., i. 232.
Valentine's Bank, pipe-ore, i. 500.
Valleys of anticlinal form, i. 8—the Appalachian chain, i. 15—boat-shaped, i. 8.
Valley Creek, Aur. limest. belt, i. 211.
Valley Church, limest. quarries, i. 214.
Valley Forge, ii. 676—Creek, exposure of Pri. rocks, i. 180—limest. quarries, i. 214—Pri., i. 151—Pri. strata, i. 158.
Valley of French Creek, anticlinal, i. 86.
Valley Furnace, Little Tracey Coal, ii. 219.
Valleys of elevation, ii. 922, 923—of syn. structure, i. 8.
Vanartsdalen's crystalline limest., i. 224.
Vandermark's Hill, ii. 385, 398.
Van Stork Coal Company, ii. 355—Mine, ii. 341.
Vansant's Quarry, i. 153.
Vegetable fossils of coal, ii. 811.
Venango County, ii. 491.
Venison Hill, ii. 367.
Vergent flags in Bradford County, i. 295—in Catawissa, i. 140—character and thickness, i. 108—(escarpment), i. 285—diagonal lamination, i. 296—near Huntingdon, i. 140—in Bradford and Tioga, i. 114—in Lake Erie, i. 578, 579—southern escarpment, i. 287—south of Huntingdon, i. 520—thickness, i. 580.
Vergent iron ore, Canoe Run, i. 550—rocks, i. 113—Bald Eagle Valley, i. 540—in Erie and Crawford counties, i. 580—north of Lehigh Water-gap, i. 274—from Muncy to Milesburgh, i. 548—in north-eastern district, i. 294—north-west of the Tunkhaunock Hills, i. 305.
Vergent series, ii. 487, 488, 498, 524, 549, 756.
Vergent shales, i. 356—between Belmont and Stockport, i. 306—in Bradford and Tioga counties, i. 297—features of deposition, i. 298—fossils, i. 108—near Huntingdon, i. 141—on the Lehigh, i. 141—lithological features, details, i. 297—in the Seventh District of Palæozoic region, i. 117—south of Corning, &c., i. 311—Tioga River above Covington, i. 310—thickness, i. 580—thickness at Huntingdon, i. 297—betweeu Tunkhannock and Towanda, i. 297—Tuscarora syn., i. 390.
Vergent period, ii. 749—series, physical geography of, ii. 792.
Vergent strata, ii. 546—in Perry County, i. 355, 356—thickness of, i. 140, 141.
Vergent and Umb. strata beyond the Lehigh, ii. 4.
Vertical coal, ii. 59.
Vespertine, ii. 488—Astonville, ii. 143—cliffs, Susquehanna, ii. 533—conglomerate, i. 118, 119, ii. 467—Berry's Mountain, i. 365—Big Scrub Ridge, i. 431—character and thickness, i. 108—north-eastern district, i. 301—Pottsville, ii. 9.
Vespertine, modifications in type, &c., ii. 467—ore, ii. 610—period, ii. 749—rocks, i. 529, ii. 508, 517, 520, 525,—anthracite region, ii. 7—between Belmont and the Delaware, i. 305—bituminous coal region, i. 119—Brookville, ii. 583—composition, &c., ii. 8—base of the Pokono Mountain, i. 280—above the Great Eddy, i. 304—Loyalsock, i. 22—Mauch Chunk, on the Lehigh, i. 143—near Pottsville, i. 143—between Mount Moriat and Honesdale, &c., i. 304—Moosic Mountain, i. 304—northern limit, i. 306—syn. basins, ii. 12—Trough Creek Valley, i. 532, 533—north-west of the Wyoming Basin, i. 305.
Vespertine sandst., i. 108, 577, ii. 4, 483, 485, 487, 493, 498, 509, 526—between Belmont and Stockport, i. 306—on the Delaware, i. 304—geographical range, ii. 11—near Knoxville, i. 312—Seventh District, Palæozoic region, i. 117.
Vespertine series, ii. 466, 523, 527, 756—physical geography of, ii. 793.
Vespertine strata in Alleghany Mountain, ii. 143—mountain-gaps of Broad Top region, i. 528—thicknesses of, i. 142, 144.
Vespertine and Umb., ii. 321.
Viaduct, ii. 494—views from the interior basins, i. 24.
Vincent's Quarry, building-stone, i. 583.
Virginia oolitic limest., i. 238—Mesozoic coal, ii. 763—Pliocene and Pleistocene, ii. 772—western border, i. 120.
Wabash Creek and Newkirk Basin, ii. 102.
Wabash Valley, ii. 96.
Wadesville, ii. 424.
Wadham's Seam, ii. 408.
Waggoner's Mill, ninth anti. axis, i. 316—Surg. ore sandst., i. 340.
Waggon Town, i. 84.
Wagner's Tunnel Coals, ii. 169.
Wakefield's Rock, Surg. fossiliferous ore, i. 432.
Wales, Great South Coal-field, ii. 977.
Walkerville, limest. rocks, i. 502.
Wallace's Mill, i. 502, ii. 616.
Wallenpaupack Pon. rocks, i. 299, 300—structure of the region, i. 303.
Walu Coal, ii. 138.
Walnut Creek, i. 578.
Walpack, axis at Strondsburg, i. 282.
Walpack Bend, i. 113—to Delaware Water-gap, Cad. rocks, i. 281.
Wapwallopen, i. 119, ii. 5—Cad. and Verg. rocks, i. 452—Mountain, i. 118—Valley, anti. axis, i. 462—Vesp. conglomerate, i. 302.
Warm Spring, Mer. sandst., i. 354—Surg. rocks, i. 343.
Warren, ii. 557—County, i. 120—topographical features, i. 576—ironworks, i. 419, 424, 429—section, ii. 597—Vespertine, i. 144.
Warrior Path Gap, Ser. series, i. 148—Ridge, i. 50—iron ore, i. 524—Mer. sandst., iron ore, i. 518—position, i. 513, 515.
Warwick Furnace, Aur. limest., i. 232—Iron Mines, i. 85, ii. 707, 708.
Washburn's Land, ii. 344—Mine, ii. 341—Diamond Coal-seam, ii. 354.
Washington Bank, pipe-ore, i. 499—County, ii. 648—Gap, i. 487, 489—character of str., i. 496—furnace, i. 496—Double Gap, i. 487—Run, ii. 611.
Washita Hills, ii. 747.
Waterford Bridge, Cad. slate and limest., i. 394—Lake, i. 39—Mer. sandst., i. 389.
Water-gaps, i. 28, 29.
Waterloo, Cad. and Verg. rocks, i. 393—Gap, Mer. sandst., i. 389—Sca. marls, i. 381—Sca. and Prem. limest., i. 387.
Water-shed and basin of Carter's Tuscarora Slope, ii. 30.
Water-shed, chief, i. 2—in Potter and McKean counties, i. 35—between the Conestoga and South Branch of French Creek, i. 179.
Water-sheds, i. 39, 40.
Water Street Gap, Lev. red sandst. and white sandst., i. 129, 130—scenery, i. 50.
Watham's Coal, ii. 412.
Wave-like form of upraised strata, ii. 885.
Waves, their forms, ii. 888.
Waynesburg, Aur. str., i. 258—Cad. older black slate, i. 400—Coal, ii. 19, 506, 507, 647, 650—and Emmetsburg turnpike, i. 206, 207—limest. valley, i. 204—Pri. sandst., anti. flexures, i. 204—Surg. and Sca. rocks, i. 413.
Wayne County, carb. rocks, ii. 4—Township, calc. limest., i. 584.
Weaver's, on Muddy Creek, anti., ii. 160, 161.
Welche's Knob, i. 334—18th and 19th anti. axis, i. 317—iron sandst., i. 344—Surg. rocks, i. 343.
Wellsborough, ii. 484, 485—limestone, i. 312—mountain escarpment, i. 312—Pon. rocks, i. 300—Valley, ii. 524—Vesp. rocks, i. 143.
Welsh Mountain, ii. 3—anticlinal, i. 221, 222—Pri. white sandst., i. 156—Pri. rocks, i. 111, 178, 179.
Well's Valley, flexures of str., i. 530.
Weposening, anti. axis, i. 306.
West Beaver Creek, ii. 244.
West Branch, ii. 426—Basin, Broad Mountain, ii. 224—of the Brandywine, gneissic rocks, i. 84, 177—coal-basin, details, ii. 226—Gap, Twin Vein, ii. 170—Mine Hill Gap, Black Valley Coal, ii. 217—Primrose Coal, ii. 217—river drainage, i. 35—stream, anti. axis, ii. 162—Susquehanna, i. 120, 140—Susquehanna Cad. and Verg. rocks, i. 452—Valley, ii. 84—scenery, i. 31.
West Branch and Wolf Creek, ii. 230.
West Caln Township, Pri. str., i. 177.
West Chester Barrens, serpentine belt, i. 168, 169—serpentine in use, i. 169.
West-end Northern Coal-field, ii. 404.
Western Middle Coal-basins, i. 118—field, ii. 7—Umb. red shale, ii. 12, 265.
Western Mine Hill, structure, ii. 200.
Western Shade Mountain, i. 367.
Western Shamokin Coal-field, ii. 316.
Western slope of Pennsylvania, climate, i. 52.
West Grove Friends' Meeting-house, i. 226—limest. quarries, i. 227.
West Mahantango Creek, i. 115.
West Marlborough Inn, serpentine, 169—Bailey's limest. quarry, i. 229—township, limest. quarries, i. 230.
Westmoreland, Umb. rocks, ii. 11.
West Norwegian, ii. 35, 141, 143, 424—Creek Valley, mining details, ii. 85—Little Diamond Coal, ii. 148—Upper Sandrock Coals, ii. 162.
West Peach Mountain Basin, ii. 44.
West Pikeland Township, syn. axis, i. 86.
West Salem Colliery, ii. 186.
West-town, mica slate, i. 77.
West Vincent Township, syn. axes, i. 86.
West-West Branch, ii. 431—anti. axis, ii. 160—Big Diamond Coal, ii. 153, 154—Black Valley Coal, ii. 217—mining details, ii. 84—Peach Mountain Coal, ii. 34—synonyms of the coals, ii. 223.
"Weygatt," i. 94.
Whampoa Hill, ii. 576.
Wharton Slope, ii. 248—Vein Tunnel, ii. 245.
Wheatfield Mines, ii. 717.
Wheatley's, ii. 676.
Wheatley Lode, ii. 700—in 1853, ii. 703.
Wheeler and Miller's Colliery, ii. 440.
Wheeling, ii. 506.
Whip's Cove, Pon. rocks, i. 533.
White-ash anthracite coals, ii. 66, 290, 308—east of Dado's Tunnel, dip, ii. 37, 233—east of Klinger's Gap, ii. 164—Klinger's Gap, ii. 189, 328—Eastern Mine Hill, ii. 200—Mill Creek, ii. 229—Donaldson Basin, ii. 181—Mill Creek, ii. 420—south-west branch of Mine Hill Basin, ii. 211—Silver Creek, ii. 228—south of the Swatara Falls, anti., ii. 155—Tamaqua, ii. 76—Tamaqua to Buckville, ii. 222—Thick Mountain, ii. 231—West Branch and Wolf Creek, ii. 230—(Lower and Upper Groups), Little Schuylkill, ii. 227.
White-ash Mammoth Coal in basin of Carey's Shaft, ii. 38.
Whiteclay Creek, hornblendic gneiss rocks, i. 81, 82—limest. quarries, i. 227.
Whitedeer Creek, i. 457—anti. axis, i. 466—Surg. red shale, Sca. limest., i. 455.
Whitedeer Hole Valley, i. 116, 455, 489—Cad. and Verg. rocks, i. 439—Prem. limest., i. 453.
Whitedeer Mountain, i. 485—Lev. white sandst., i. 458—pictorial sketch, i. 50—Lev., Surg., and Sca. strata, i. 458.

Whitedeer Valley, i. 116, 489—Cad. shales, i. 139—Mer. rocks, i. 137, 138.
Whitehaven Railroad, ii. 377—turnpike exposures on, ii. 383.
Whiteley Creek, ii. 647.
Whitemarsh, anti. ridge, i. 163—marble quarries, i. 215.
White Mountain, i. 481—origin, i. 457.
White Oak Hollow, ii. 323—Run, conglomerate, ii. 333.
White River, ii. 771, 772.
White Stone Valley Lev. and Surg. rocks, i. 512, 513.
Whitestown, ii. 690.
White's Colliery, ii. 437.
White Sulphur Spring, i. 511.
Whitfield's Lower Tunnel, White-ash Coals, ii. 86—Tunnel, ii. 104—Upper Tunnel, Big Coal, ii. 105—Mammoth Coal, ii. 216.
Wickert's Mine, ii. 725.
Wiconisco Basin, ii. 163—boundaries, dimensions, ii. 27—Basin, ii. 20, 164, 440—details of the strata, ii. 189—Klinger's Gap, ii. 190.
Wigfield's Mill, section, i. 510.
Wildcat Mountain, anti. flexures, i. 289—Ridge, i. 337, 392—belt of limest., i. 346—Cad. and Verg. rocks, i. 357—Mer. sandst., i. 351—and Valley, Cad. and Verg. rocks, i. 391—structure, i. 357.
Wildcat Valley, i. 114—Pon. red sandst., i. 363.
Wilcox's, ii. 551—Coal, ii. 374, 375—Mine, ii. 368.
Wilkesbarre, ii. 377—Basin, ii. 380—Company's Coal, ii. 394—Coal-seam, ii. 322—Nanticoke and Shickshinny districts, ii. 376—details of the coals, ii. 330—turnpike coal-boring, ii. 262—Pon. rocks, i. 286.
William Penn Colliery, ii. 429—furnace, i. 164—(No. 1) gneissic rocks, i. 73, 74—(No. 2) small quarry, i. 75—furnace No. 1, gneissic rocks, i. 79.
Williams Valley, lower conglomerates, ii. 179—10th anti. axis in the Umb. red shales, i. 316.
Williamsburg, Aur. rocks, i. 505.
Williamsport, coal at, ii. 641.
Will's Creek, coal-basin, ii. 15—Mountain, i. 19, 117.
Will's Mountain, i. 117—anti. axis, i. 469—Prem. and Mer. strata, i. 562—anti. flexure, i. 510—anti. knobs, i. 566—Cad. and Verg. rocks, i. 569—Surg. rocks, . 560—strata at the Maryland Line, i. 567.
Willistown, serpentine, i. 169, 170.
Willow Grove, belt of Prim. rocks, i. 111, 122—limest. basin, i. 159—Prim. sandst., 122—Tavern, Prim. rocks, i. 206—Prim. rocks, 155—turnpike, Prim. rocks, i. 160—Surg. rocks, i. 571.
Wilson's Creek, ii. 523.
Wilsonville, oxide of manganese, i. 304.
Wind, at Carlisle Barracks, i. 57, 58—at Pittsburg, i. 57, 58.
Wind-gap, i. 7—position and structure, i. 287—Post-mer. limest., i. 282—road, i. 95—Sca. limest. quarry, i. 287—Surg. red shales, i. 287.
Wind-gaps, i. 28.
Wind-river Mountains, ii. 747.
Winds, i. 57—dominant in Pennsylvania, i 57, 58—at Fort Mifflin, i. 58.
Windy Harbour Colliery, ii. 419.
Wire-ropes, ii. 74.
Wissahickon, anti. belt of Prim. rocks, i. 164—Creek, talc-slate, steatite, and serpentine, i. 72—section, i. 72—serpentine belt, i. 167—gneissic rocks dip, i. 97—micaceous and hornblendic gneiss, i. 71—mica slate, i. 77—northern tract of gneiss, i. 77—Prim. series, i. 122—thickness, 154, 155—Prim. strata, i. 158, 159—steatite and serpentine, i. 167.
Witchita Mountains, ii. 747.
Wolf Creek, ii. 225, 429—Primrose Coal, ii. 217—Little Diamond Coal, ii. 148—Spencer Coal-seam, ii. 153—Aur. limest. exposures, i. 242.
Wolf's Old Quarry, i. 95.
Womelsdorf iron ore, i. 251.
Wompum Hill, ii. 567.
Wood's Chrome Mine, i. 171.
Woodcock Valley, character, &c. of the formations, i. 522—Sca. limest., i. 518—structure, position, i. 523—Surg. ore, i. 516—at Trough Creek Gap, i. 524.
Woodley's Mill, Cad. and Verg. rocks, i. 548.
Woodside, ii. 432—anti., ii. 41.
Woodstock Valley, Mer. sandst.. i. 525.
Woodville Colliery, ii. 438.
Worral's ore-bank, Surg. fossiliferous ore, i. 432.
Worthen, Mr, cited, ii. 964.
Worthington, ii. 492, 595.
Wortz's Well, ii. 605.
Wray's Hill, ii. 24, 449, 451—iron ore, i. 530—Pon. rocks, i. 527.
Wright's Coal, ii. 109, 398, 564.
Wurth's Farm, serpentine and steatite, i. 169.
Wyalusing, ii. 482—springs of salt water, i. 306—Falls, ii. 480—anti., i. 295, 305.
Wyoming Basin, boundaries, ii. 21—conglomerate, ii. 23—Pon. strata, i. 142—Umb. rocks, ii. 10—Umb. series, i. 144.
Wyoming Coal-basin, i. 116, 119—general structure, ii. 323—Pon. rocks, thickness, i. 300—Vesp. rocks, i. 143.
Wyoming Coal Company, ii. 402.
Wyoming Coal-field, i. 15, 48, 294, ii. 3, 6—Vesp. strata, il. 8.
Wyoming Coal Valley, i. 452.
Wyoming and Kingston Flats, drift, i. 48.
Wyoming, Kingston, and Plymouth District, ii. 405—details of the coals, ii. 330.
Wyoming and Lackawanna Basin, general view of the strata, details, ii. 319—Seral series, i. 147—undulations of the Coal-measures, ii. 324.
Wyoming Mountain, mono. crest, i. 15.
Wyoming Valley, i. 48—scenery, i. 31.
Wysock's Bend, ii. 482.
Wysox Creek, Verg. and Pon. strata, i. 306.
Xander's Mine, ii. 723.
Yankee Run, Nittany Mountain, i. 492.
Yard Coal, ii. 138—Mill Creek, ii. 173, 219—of East Norwegian, ii. 135, 136.
Yates' Coal, ii. 366, 367, 374.
Yellow Breeches Creek, i. 203, 257, 258, ii. 678.
Yellow Creek, i. 504, 507—Gap, i. 529—iron ore, i. 525.
Yellow Springs, Aur., i. 231—iron-ore deposits, i. 87.
Yellow Spring Gap, Seral series, i. 146—outcrops of the coal-beds, ii. 196—Run, ii. 610.
Yellow Tavern, conglomerate, i. 102.
York Aur. limest., i. 222—Company's Coal-basin, ii. 248—Slope Colliery, ii. 247—County, anti. belt of Pri. slate, i. 184—flexures, i. 192—slate quarries, i. 188.
York Furnace, Otter Creek, limest. band, i. 187.
Yorkhaven, ii. 657.
Yorkshire and Great Central Coal-field, ii. 979.
York Springs, ii. 689—Tunnel, ii. 42, 434—Deep Run, ii. 177.
York Valley, limest. belt, i. 185.
Young Man's Town, i. 457.
Young's Tavern to Rangler's Mill, i. 457.
Young Woman's Town, ii. 526, 534.
Young Woman's Creek, i. 50.
Youngstown, ii. 488.
Youghiogheny, ii. 25, 498, 499, 503—River, i. 33, ii. 615—sections, ii. 621, 624, 636, 637, 641, 660.
Youghiogheny section, ii. 610, 611.
Youhiogheny Valley, ii. 665.
Zachariah's Run, ii. 128, 419—coal-beds, ii. 91—collieries, ii. 31—coal-mines, ii. 85—details of coal-beds, ii. 123—section, i. 129—synonyms of coals, ii. 222.
Zelienople section, ii. 579.
Zeolite in interstices of trap-rock, ii. 692.
Zerbe's Gap, ii. 309—coal-seams, ii. 309, 311—Coals, ii. 313, 314—Rennie Coal, ii. 308—Seral series, i. 147—Twin Coal, ii. 300.
Zerbe's Run, ii. 308—coal-seams, ii. 311—coal, ii. 1014—and Shamokin Coal-lands, ii. 309.
Zeuglodon cetoides, ii. 769.
Zinc Mine, north of Friedensville, i. 236—near Saucon Valley, i. 101.

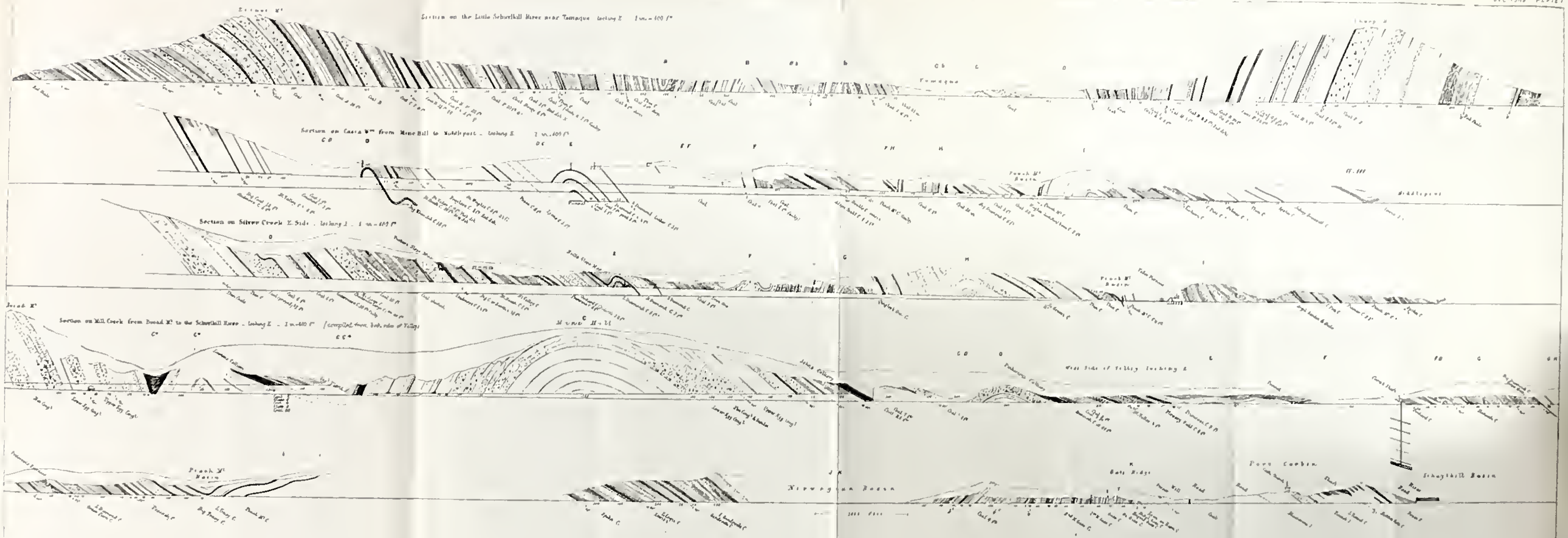
THE END.

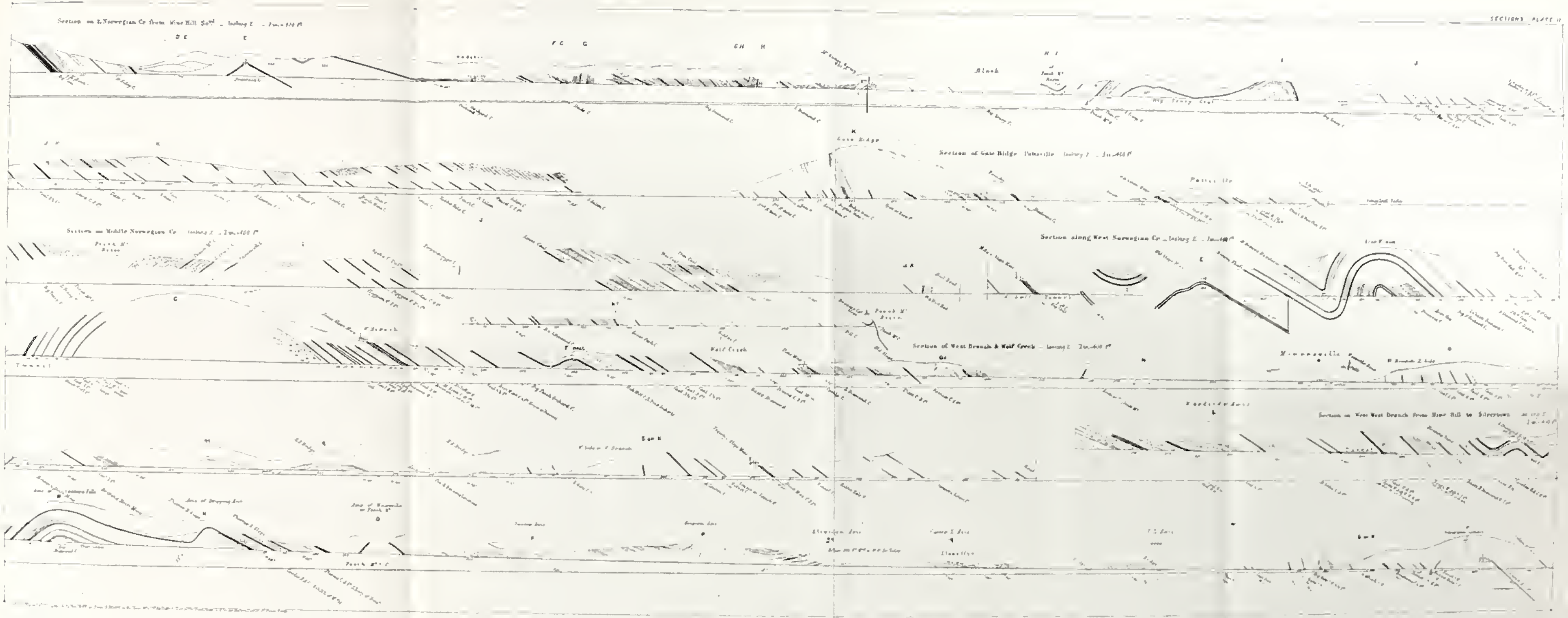
PRINTED BY WILLIAM BLACKWOOD AND SONS, EDINBURGH.

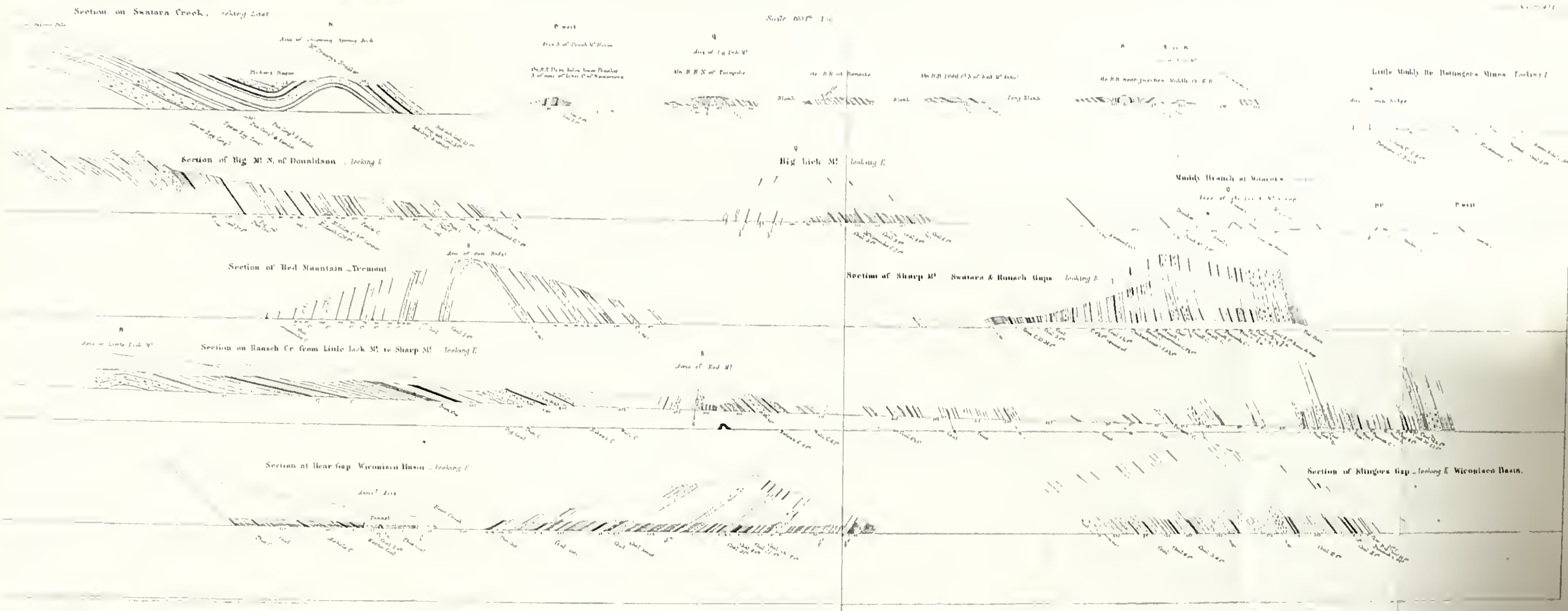
ERRATA IN VOL. II.

Page 7, line 24, after *Part II. of*, read *the lower carboniferous strata, their, &c.*
„ 14, line 42, erase *Levant.*
„ 86, line 39, for *Mills* read *Milnes.*
„ 110, line 33, for 600 read 575.
„ 110, line 35, for 100 read 70.
„ 110, line 38, for 2 read 7.
„ 110, line 39, for 4 read 5.
„ 113, line 16, for 400 read 55, and for 450 read 470.
„ 113, line 19, for 303 read 635.
„ 153, line 20, before *White-ash Coal* insert *Anderson.*
„ 171, line 22, for 169 read 134.
„ 171, line 26, for 85 read 65.
„ 172, line 14, for 200 read 187.
„ 175, line 32, for *Crescentville* read *Cressonville.*
„ 177, line 33, for *Anderson* read *Kear*, and for *Kear* read *Anderson.*
„ 185, title of woodcut, for *Hebbard's* read *Ebert's.*
„ 193, line 29, for *Bear* read *Lick.*
„ 202, line 25, for *Old Colliery Gap* read *Old Gap Colliery.*
„ 207, last paragraph, for 180 read 122.
„ 211, line 23, after *Westward*, read as a heading, *Of the north-western branch of the Mine Hill Basin.*
„ 250, under Jeanesville, for 2 *feet* 3 *inches is coal*, read 2 *feet* 3 *inches is slate.*
„ 265, line 18, after *Big Mine* read *Run.*
„ 348, title of woodcut, for *looking N.E.*, read *looking S.W.*

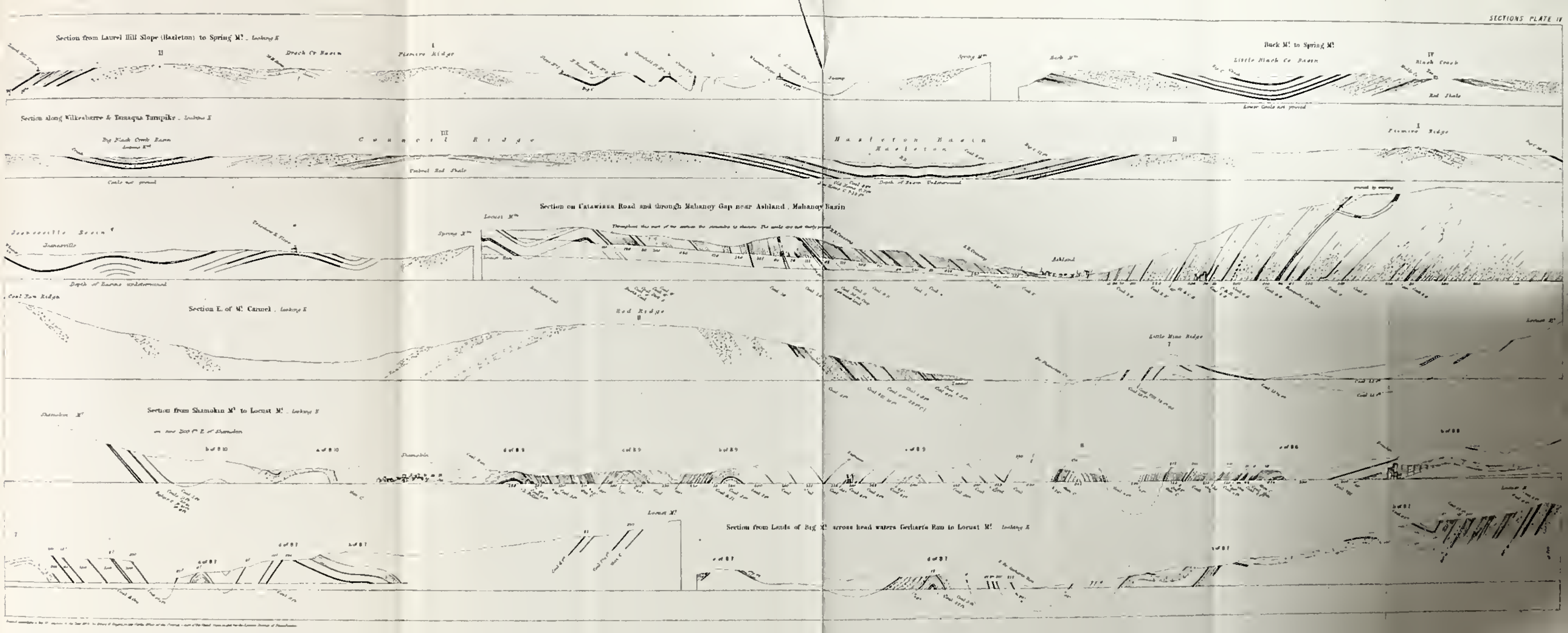
SECTIONS PLATE I

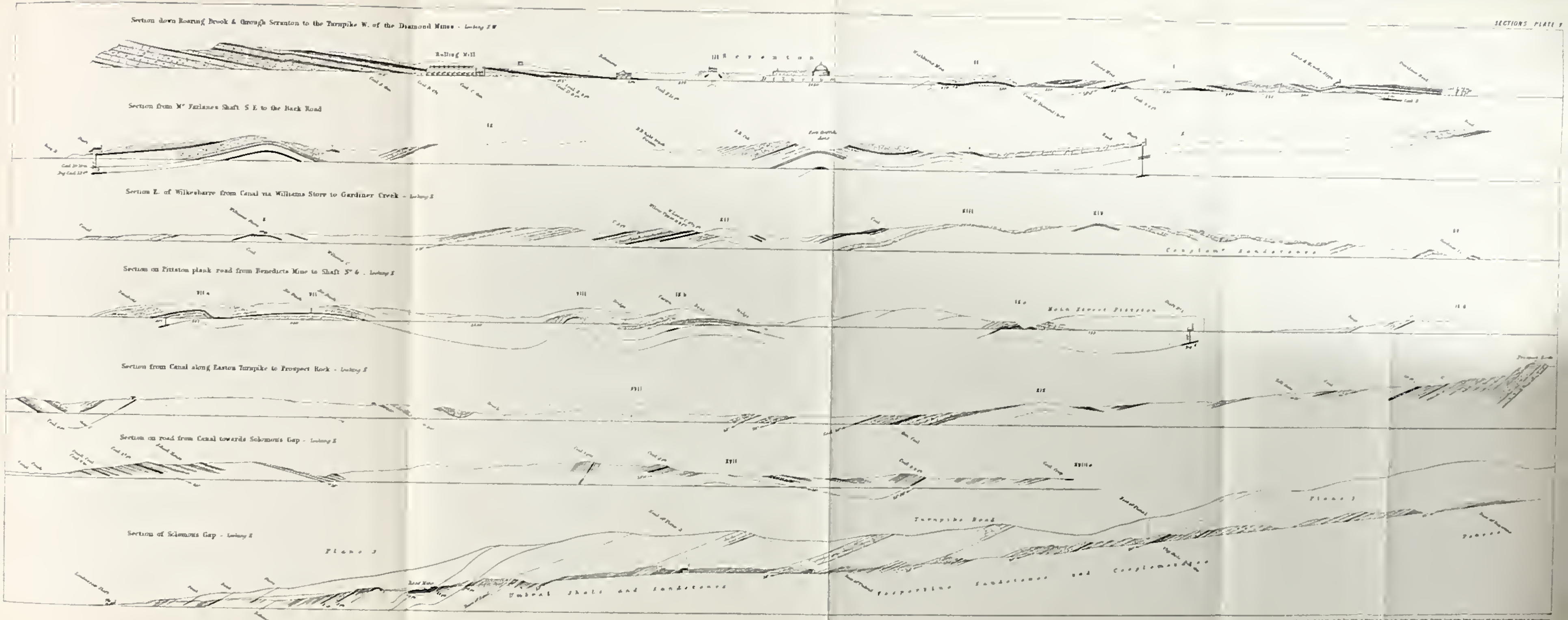

Sharp Mt
Section on the Little Schuylkill River near Tamaqua looking E 1 in. = 400 ft
Tamaqua
Section on Cass[a] from Mine Hill to Middleport _ looking E 1 in. = 400 ft
Peach Mt Basin
Middleport
Section on Silver Creek E. Side _ looking E _ 1 in. = 400 ft
Peach Mt Basin
Broad Mt
Section on Mill Creek from Broad Mt to the Schuylkill River _ looking E _ 1 in. = 400 ft (compiled from both sides of Valley)
Mine Hill
West Side of Valley looking E
Peach Mt Basin
Norwegian Basin
Bolt Ridge
Port Carbon
Schuylkill Basin


Section on E. Norwegian Cr from Mine Hill Sect. _ looking E _ 1 in. = 400 ft
Section of Gate Ridge Pottsville looking E _ 1 in. = 400 ft
Gate Ridge
Pottsville
Section on Middle Norwegian Cr. looking E _ 1 in. = 400 ft
Section along West Norwegian Cr _ looking E _ 1 in. = 400 ft
Section of West Branch & Wolf Creek _ looking E _ 1 in. = 400 ft
Wolf Creek
Minersville
Section on West West Branch from Mine Hill to Silvertown looking E
1 in. = 400 ft
Big Tracy Coal


Section on Swatara Creek, looking East
Scale 1000 ft 1 in
Axis of Swatara Gap
Pickerel Basin
Axis of Peach Mt Basin
Axis of Big Lick Mt
Blank
Long Blank
Little Muddy Br. Bettingers Mines, looking E
Section of Big Mt N. of Donaldson, looking E
Big Lick Mt, looking E
Muddy Branch at Wancers
Section of Red Mountain, Tremont
Axis of Red Mt
Section of Sharp Mt, Swatara & Rausch Gaps, looking E
Section on Rausch Cr. from Little Lick Mt to Sharp Mt, looking E
Axis of Red Mt
Section at Bear Gap, Wiconisco Basin, looking E
Tunnel
Section of Klingers Gap, looking E, Wiconisco Basin
Coal

SECTIONS PLATE IV


Section from Laurel Hill Slope (Hazleton) to Spring Mt. Looking E
II
Drech Cr Basin
I
Pismire Ridge
Spring Mtn
Back Mtn
Back Mt. to Spring Mt.
Little Black Cr Basin
IV
Black Creek
Red Shale
Lower Coals not proved
Section along Wilkesbarre & Tamaqua Turnpike. Looking E
Big Black Creek Basin
Coals not proved
III
Council Ridge
Umbral Red Shale
Hazleton Basin
Hazleton
Depth of Basin Undetermined
II
I
Pismire Ridge
Section on Catawissa Road and through Mahanoy Gap near Ashland, Mahanoy Basin
Locust Mtn
Spring Mtn
Jeanesville Basin
Jeanesville
Depth of Basins undetermined
Ashland
Coal Run Ridge
Section E. of Mt. Carmel. Looking E
Red Ridge
II
Little Mine Ridge
I
Locust Mt.
Section from Shamokin Mt. to Locust Mt. Looking E
Shamokin Mt.
Shamokin
Locust Mt.
Section from Lands of Big Mt. across head waters Gerharts Run to Locust Mt. Looking E



Section down Roaring Brook & through Scranton to the Turnpike W. of the Diamond Mines - Looking N W

Section from Mc Farlanes Shaft S E to the Back Road

Section E. of Wilkesbarre from Canal via Williams Store to Gardiner Creek - Looking E

Section on Pittston plank road from Benedicts Mine to Shaft No 6 . Looking E

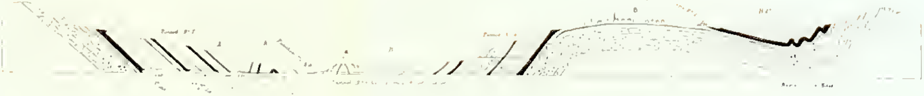
Section from Canal along Easton Turnpike to Prospect Rock - Looking E

Section on road from Canal towards Solomons Gap - Looking E

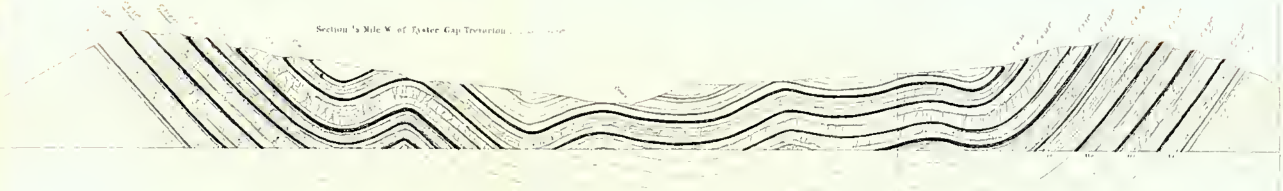
Section of Solomons Gap - Looking E

SECTIONS PLATE VI

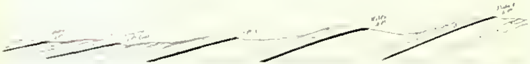
Section across the Basin at the Lehigh Summit Mines



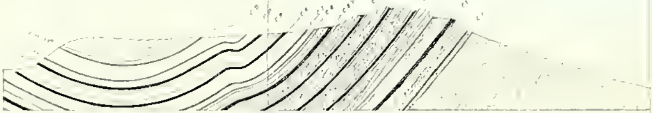
Section ½ Mile W. of Eyster Gap Trevorton



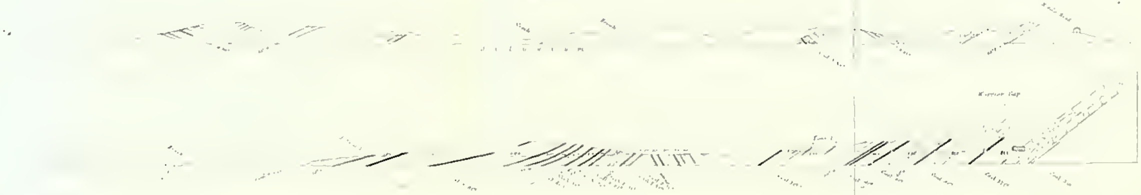
Longitudinal profile of Little Lick R.



Section W. Side of Eyster Gap, Trevorton



Section from Susquehanna R. to Warrior Path Gap



SECTION, Along the Pennsylvania Central Railroad, from Pittsburg to the Alleghany Mountain.

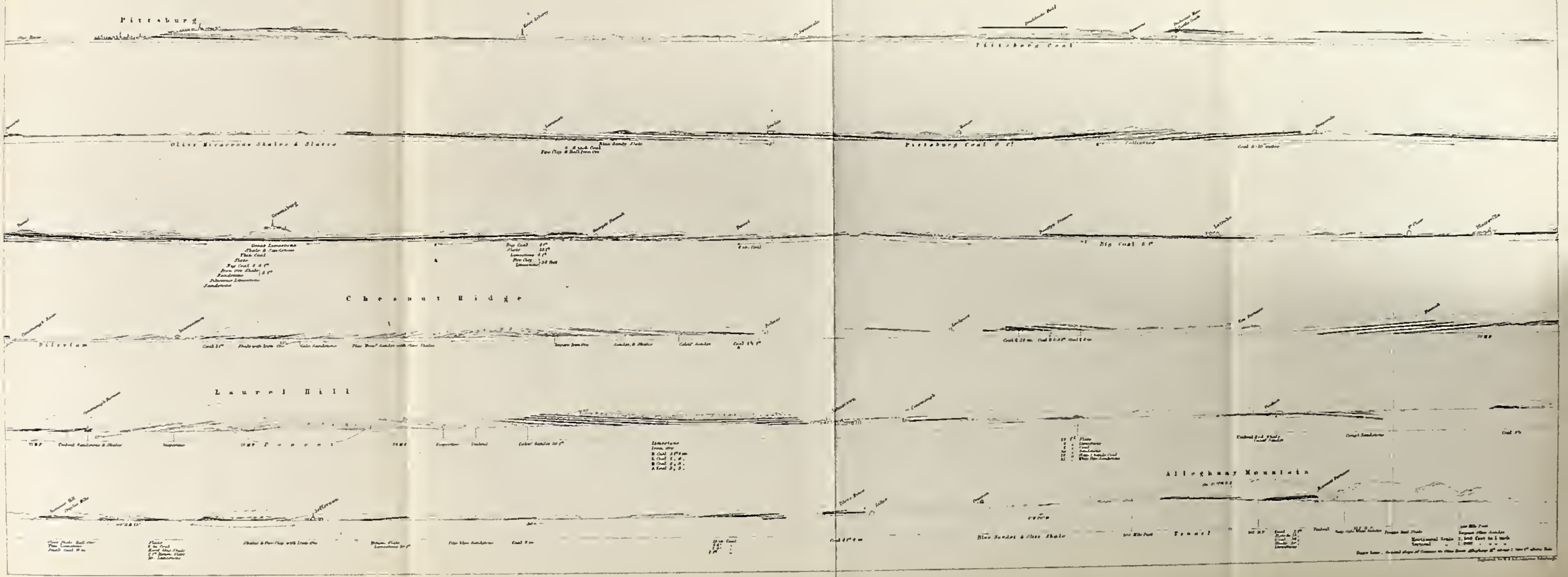
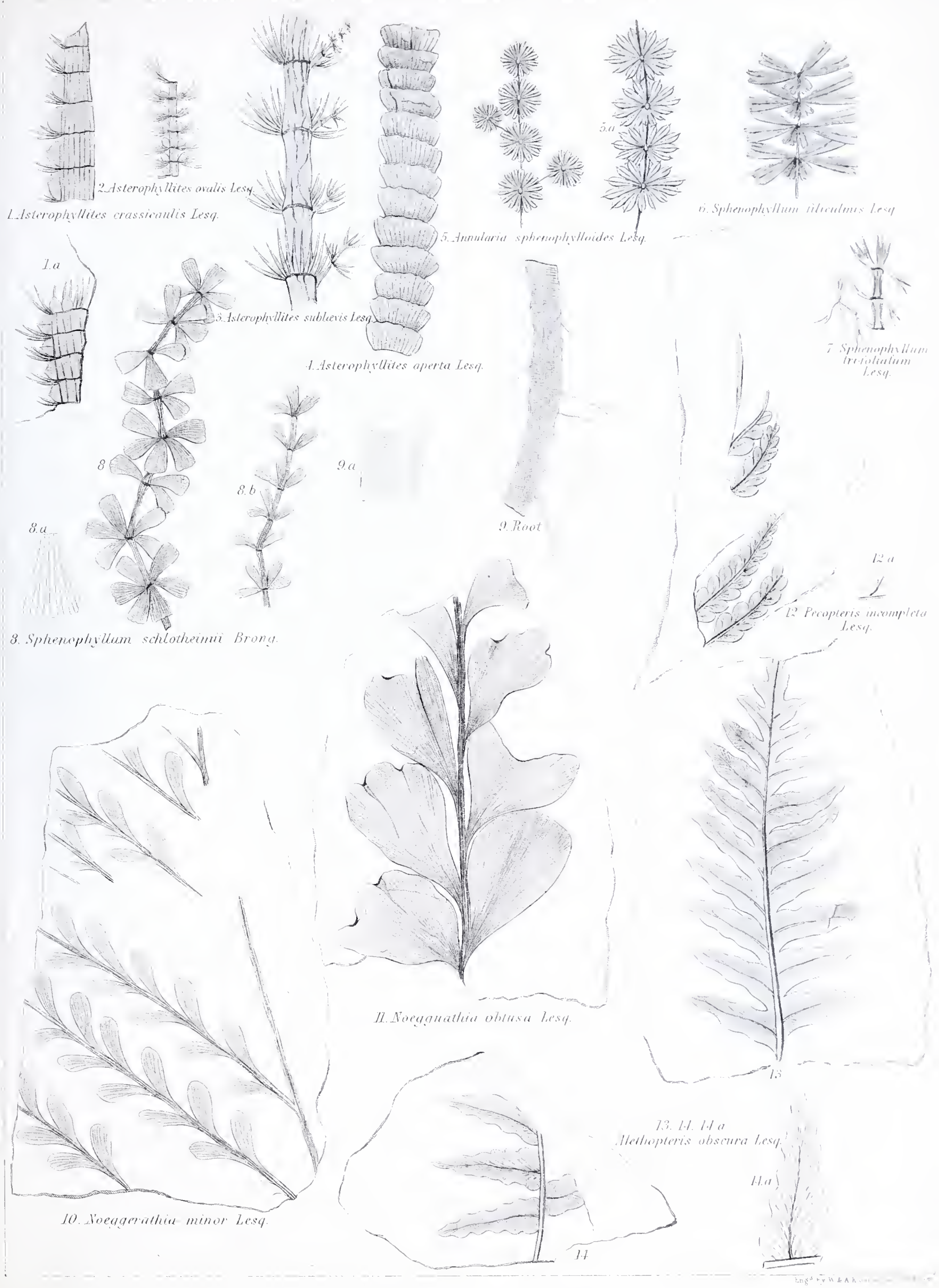
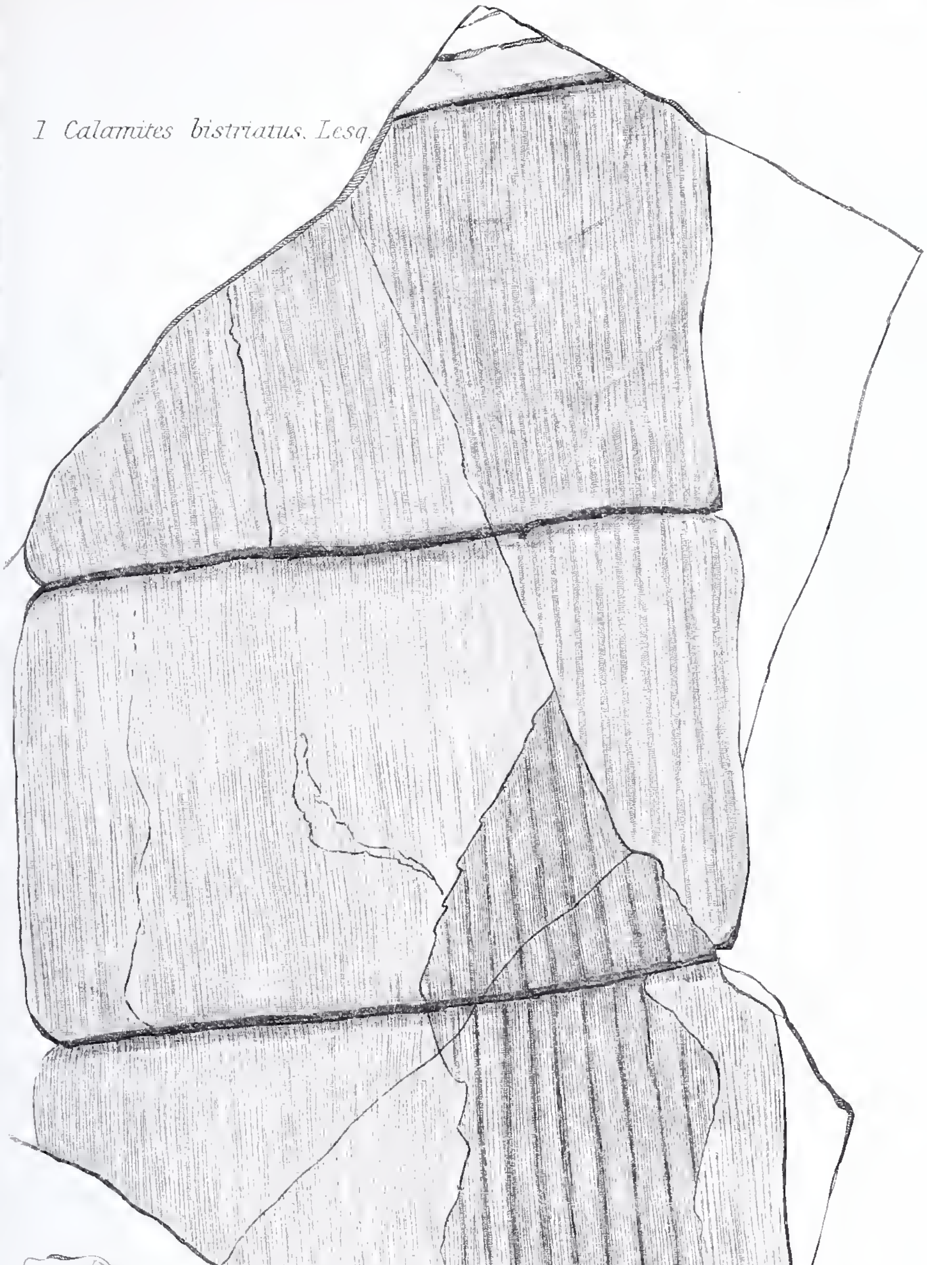


PLATE I

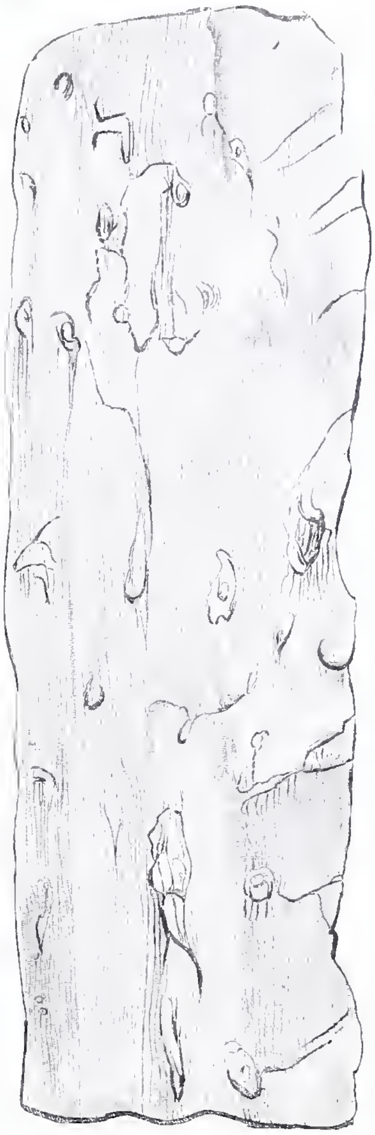

1. Asterophyllites crassicaulis Lesq.
1.a
2. Asterophyllites ovalis Lesq.
3. Asterophyllites sublævis Lesq.
4. Asterophyllites aperta Lesq.
5. Annularia sphenophylloides Lesq.
5.a
6. Sphenophyllum filiculmis Lesq.
7. Sphenophyllum trifoliatum Lesq.
8
8.a
8.b
8. Sphenophyllum schlotheimii Brong.
9.a
9. Root
10. Noeggerathia minor Lesq.
11. Noeggerathia obtusa Lesq.
12 a
12. Pecopteris incompleta Lesq.
13
13. 14. 14 a Alethopteris obscura Lesq.
14
14.a

Engd by W & A K [illegible]

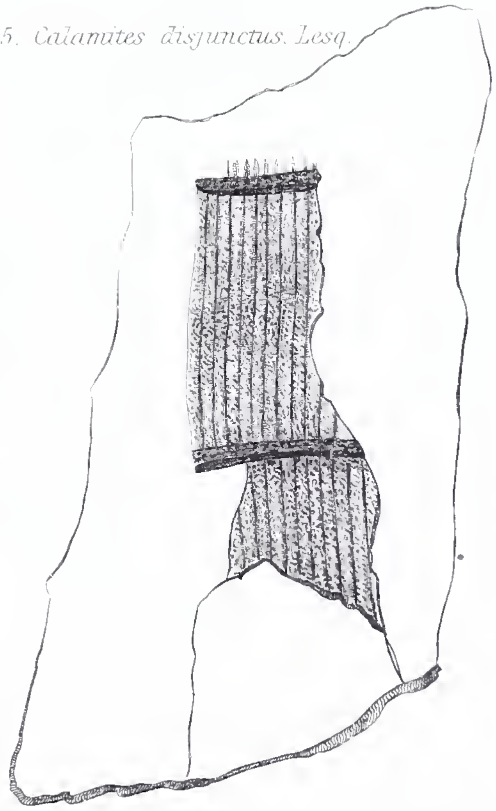
FOSSILS OF COAL FORMATION.



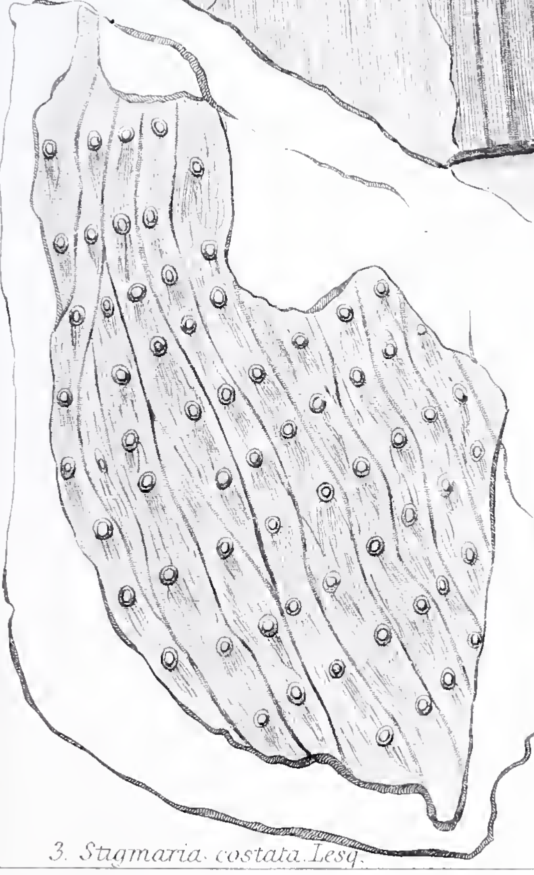
1 *Calamites bistriatus. Lesq.*



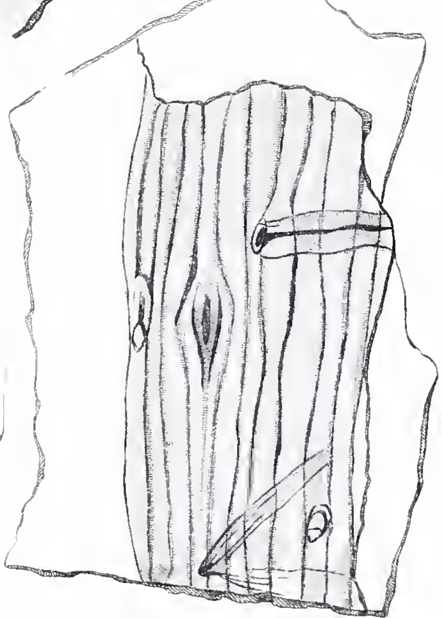
2 *Stigmaria radicans. Lesq.*



5. *Calamites disjunctus. Lesq.*



3. *Stigmaria costata. Lesq.*

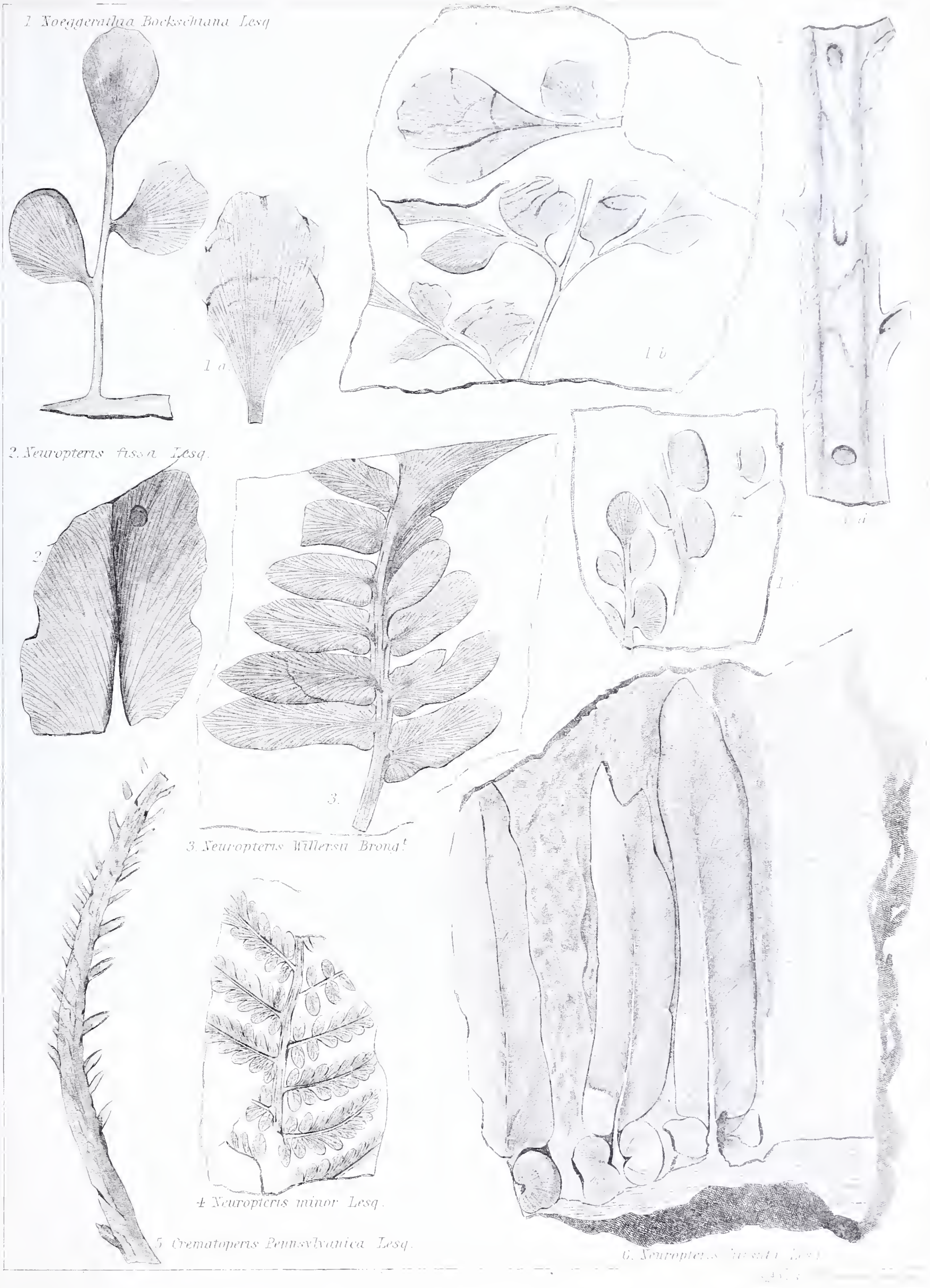


4. *Stigmaria irregularis. Lesq.*

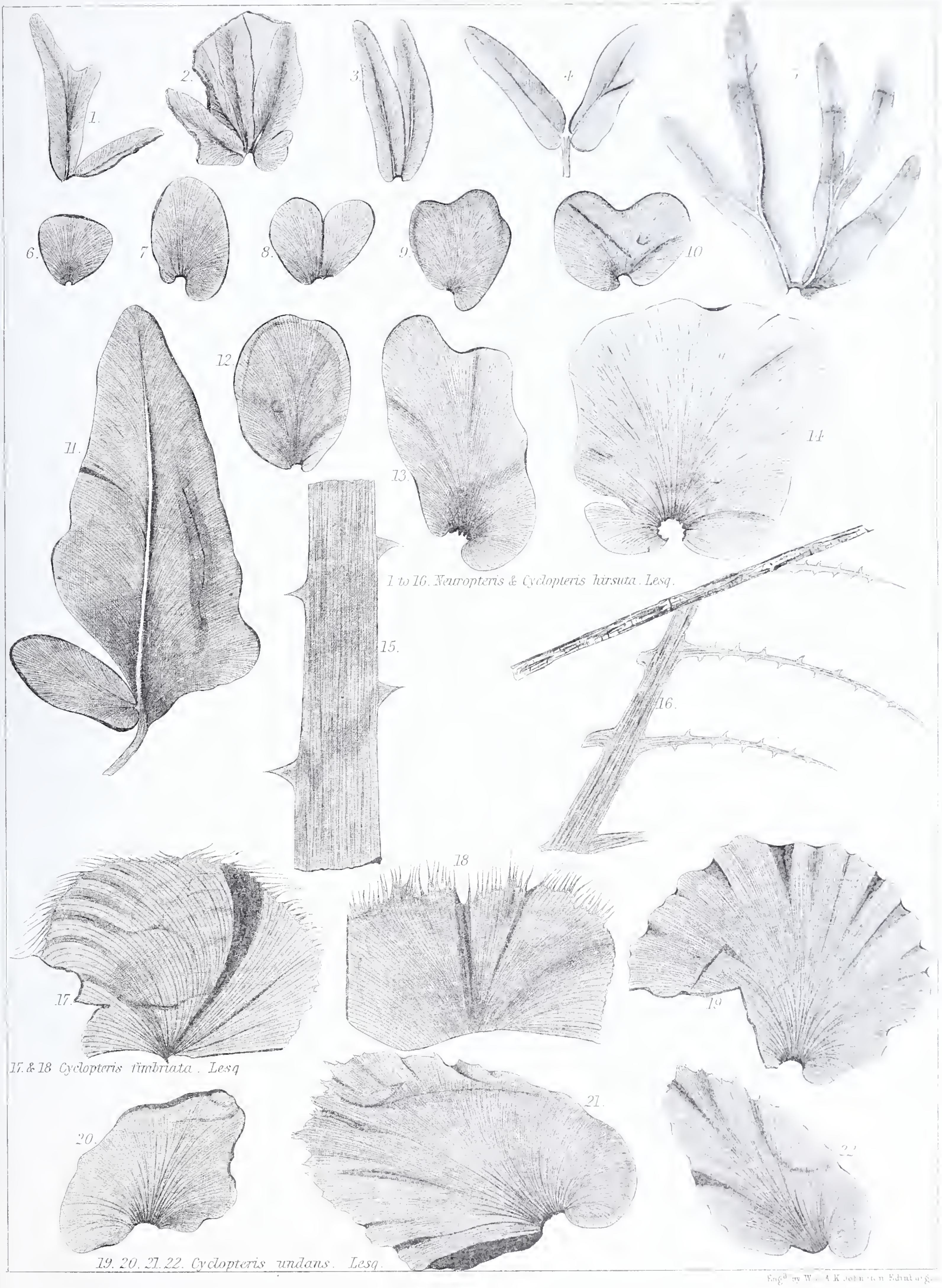
Eng^d by W. & A.K. Johnston Edinburgh.

FOSSILS OF COAL FORMATION.

PLATE III


1. Noeggerathia Bockschiana Lesq.
1 a
1 b
1 c
1 d
2. Neuropteris fissa Lesq.
2
3.
3. Neuropteris Willersii Brong.
4. Neuropteris minor Lesq.
5. Crematoperis Pennsylvanica Lesq.
6. Neuropteris hirsuta Lesq.

FOSSILS OF COAL FORMATION



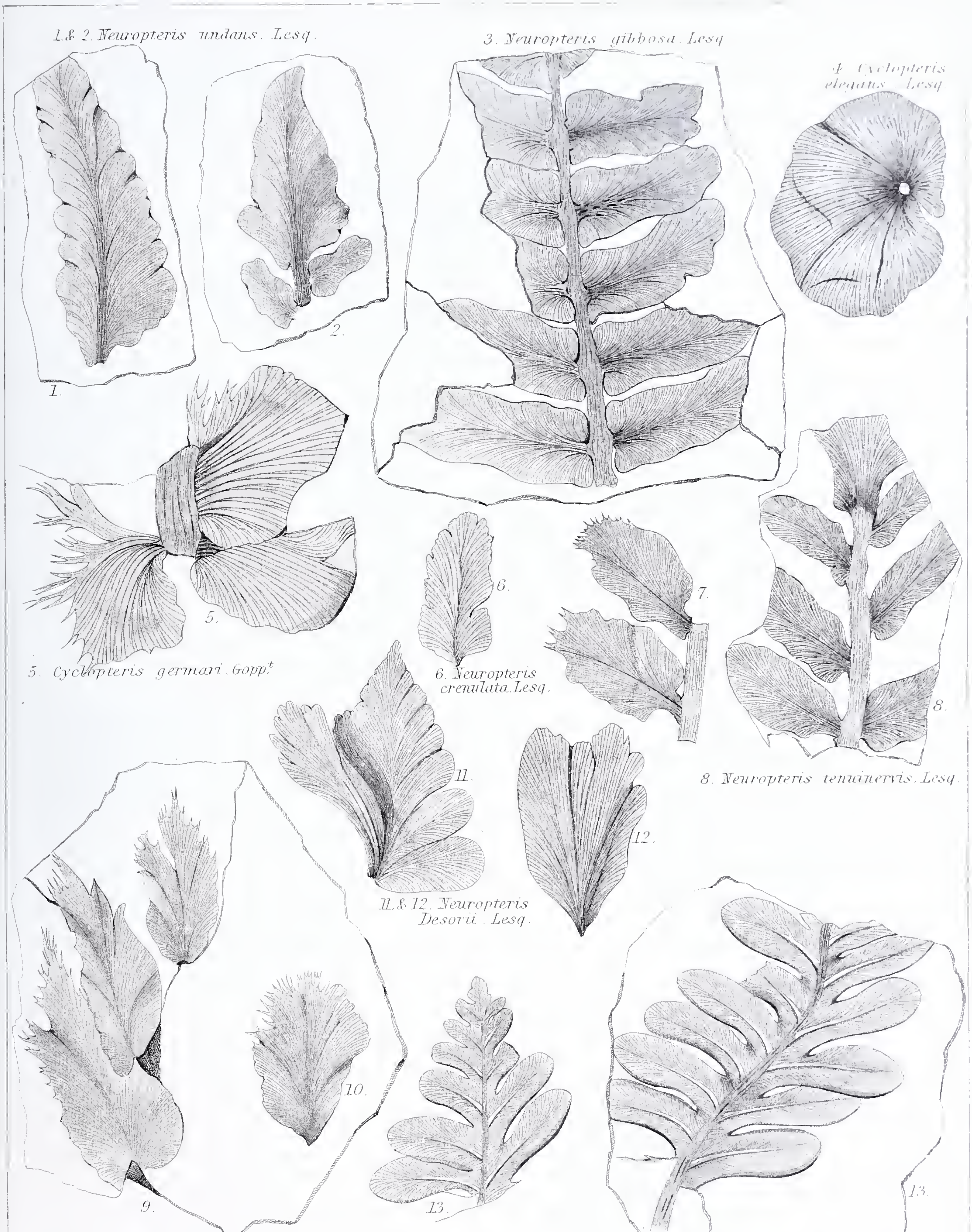
1 to 16. *Neuropteris & Cyclopteris hirsuta. Lesq.*

17. & 18. *Cyclopteris fimbriata. Lesq.*

19. 20. 21. 22. *Cyclopteris undans. Lesq.*

Engd by W. & A.K. Johnston Edinburgh.

FOSSILS OF COAL FORMATION.



1. & 2. *Neuropteris undans. Lesq.*

3. *Neuropteris gibbosa. Lesq.*

4. *Cyclopteris elegans. Lesq.*

5. *Cyclopteris germari. Gopp.ᵗ*

6. *Neuropteris crenulata. Lesq.*

8. *Neuropteris tenuinervis. Lesq.*

11. & 12. *Neuropteris Desorii. Lesq.*

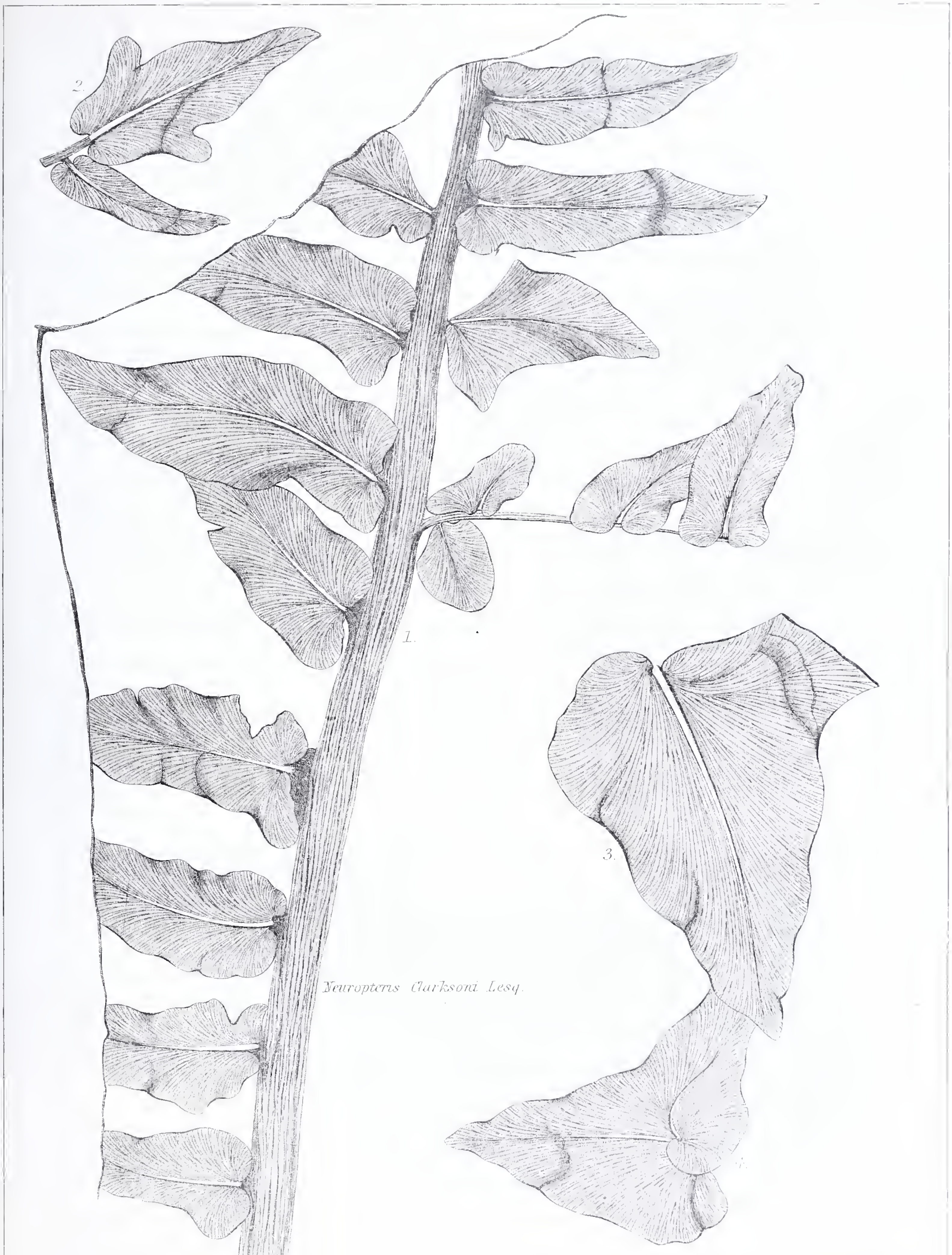
9. & 10. *Neuropteris dentata. Lesq.*

13. *Callipteris Sullivantii. Lesq.*

Engd by W & A.K. Johnston Edinburgh

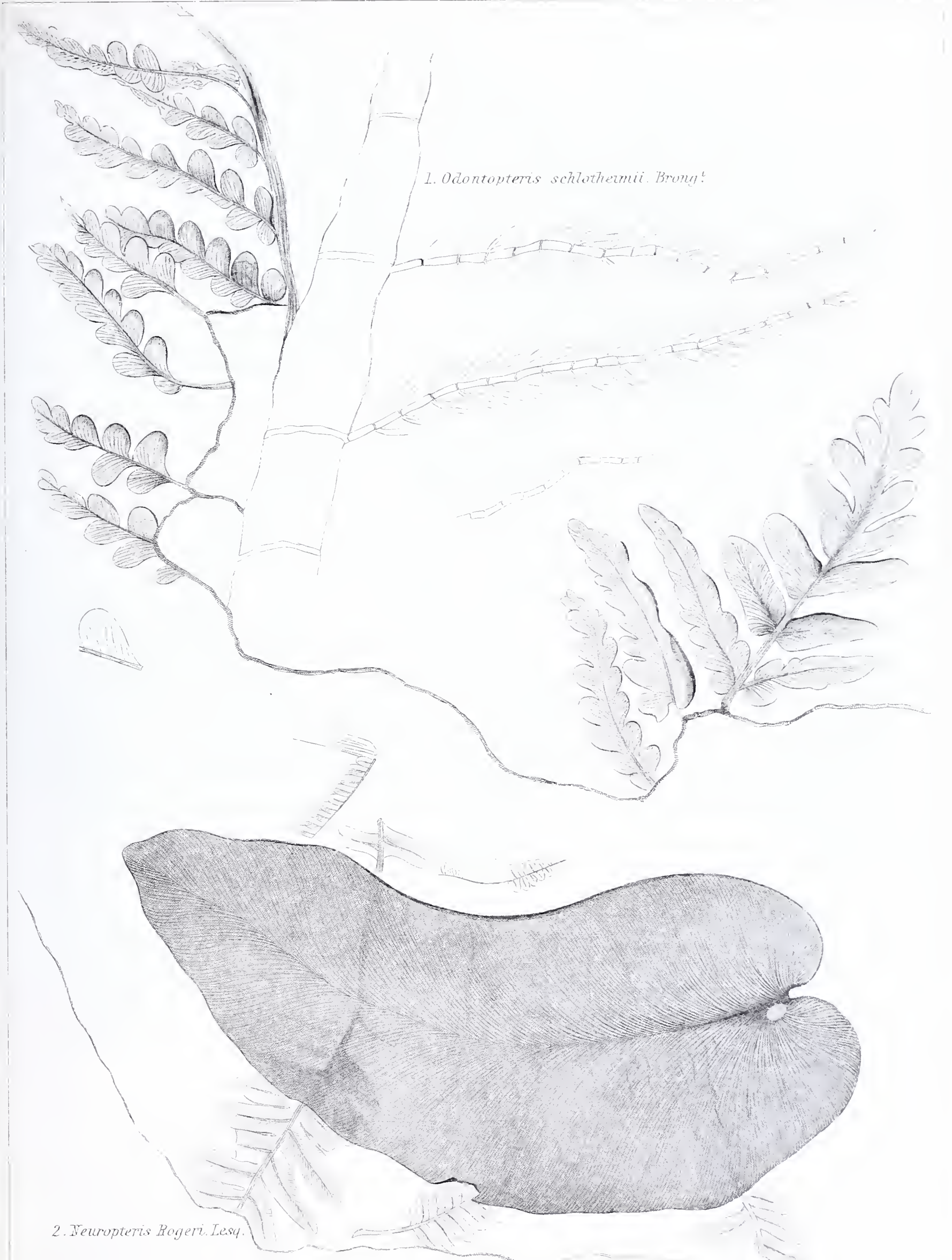
FOSSILS OF COAL FORMATION.

PLATE VI



FOSSILS OF COAL FORMATION

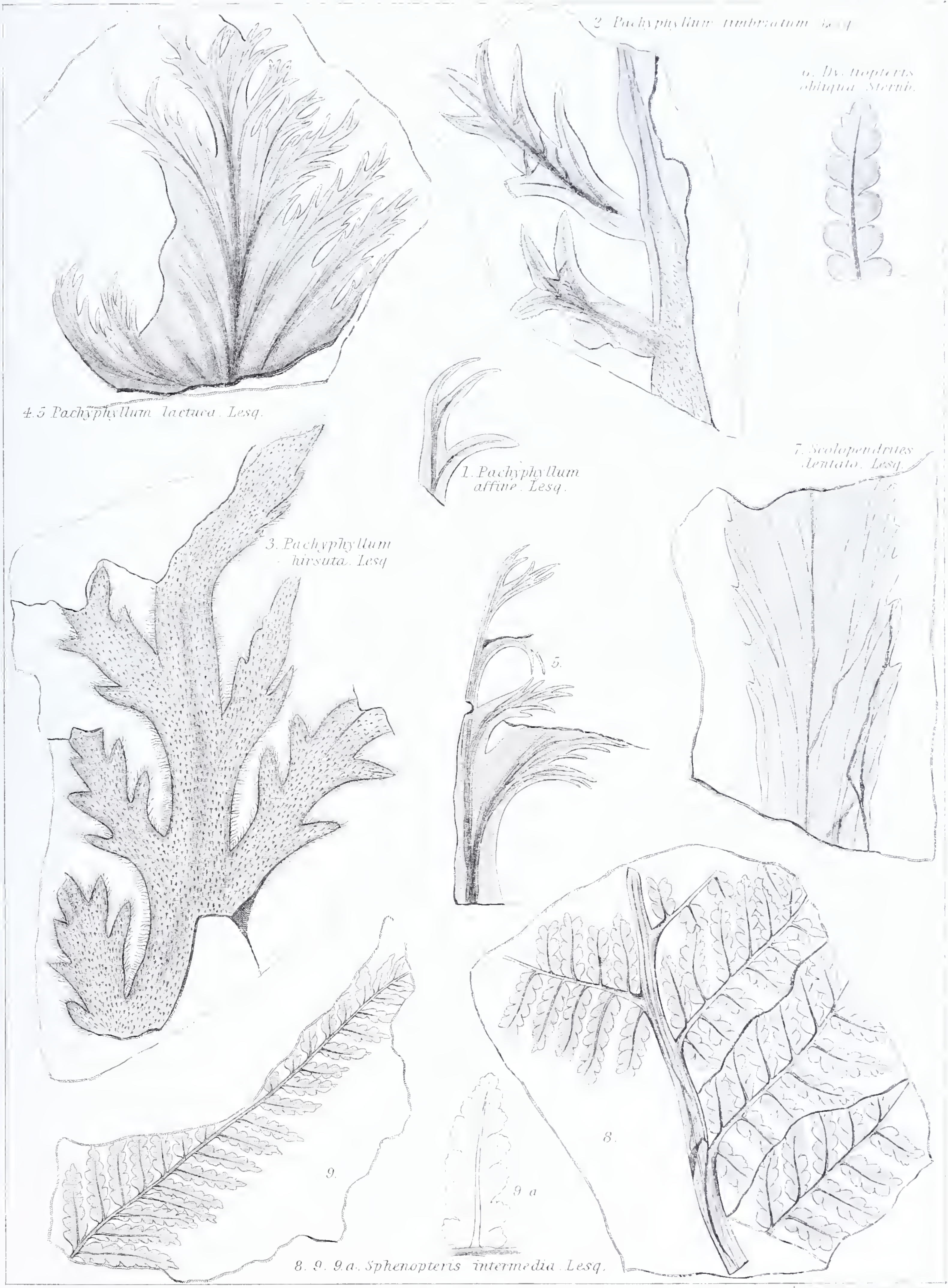
PLATE VII


1. Odontopteris schlotheimii. Brong^{t}
2. Neuropteris Rogeri. Lesq.

Eng^{d} by W. & A.K. Johnston Edinburgh.

FOSSILS OF COAL FORMATION.

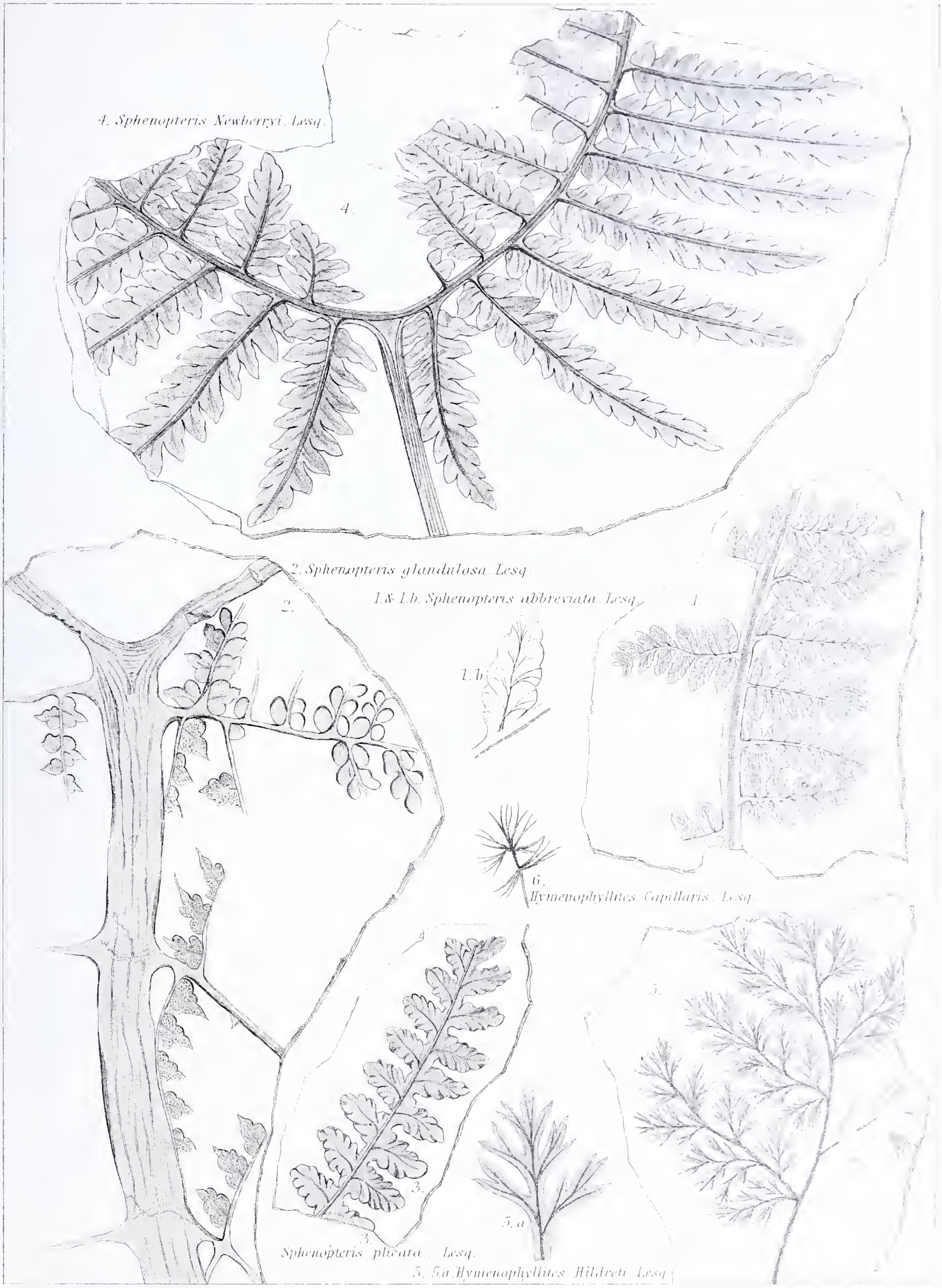
PLATE VIII.


2. Pachyphyllum imbricatum. Lesq.
6. Dictyopteris obliqua. Sternb.
4. 5. Pachyphyllum lactuca. Lesq.
1. Pachyphyllum affine. Lesq.
7. Scolopendrites dentata. Lesq.
3. Pachyphyllum hirsuta. Lesq.
5.
8.
9.
9 a
8. 9. 9.a. Sphenopteris intermedia. Lesq.

Eng^d by W. & A. K. [illegible] Edinburgh

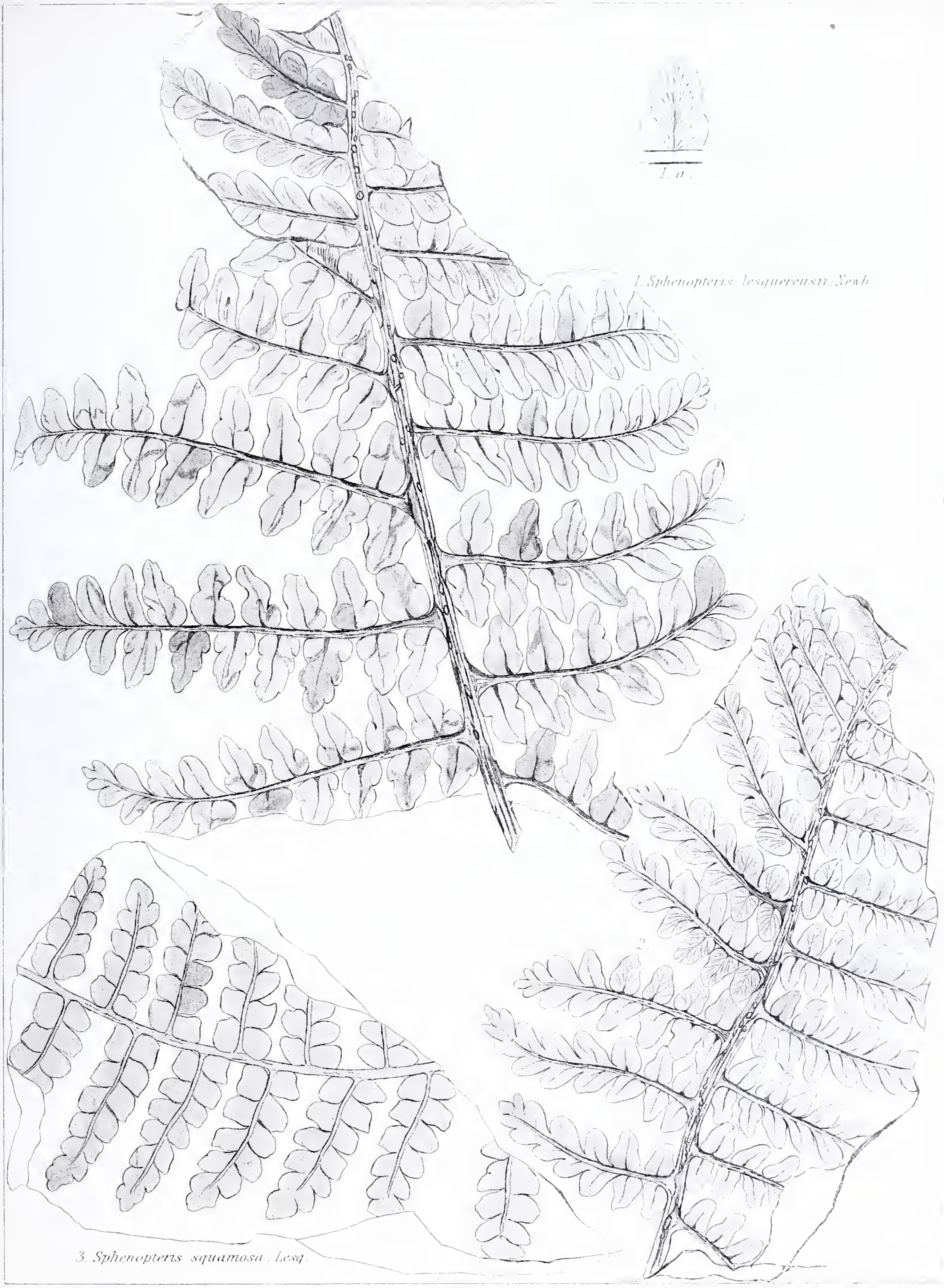
FOSSILS OF COAL FORMATION.

PLATE IX.


4. Sphenopteris Newberryi, Lesq.
4.
2. Sphenopteris glandulosa, Lesq.
2.
1.& 1.b. Sphenopteris abbreviata, Lesq.
1.
1.b.
6.
Hymenophyllites Capillaris, Lesq.
5.
3.
3.
Sphenopteris plicata, Lesq.
5.a.
5. 5.a Hymenophyllites Hildreti, Lesq.

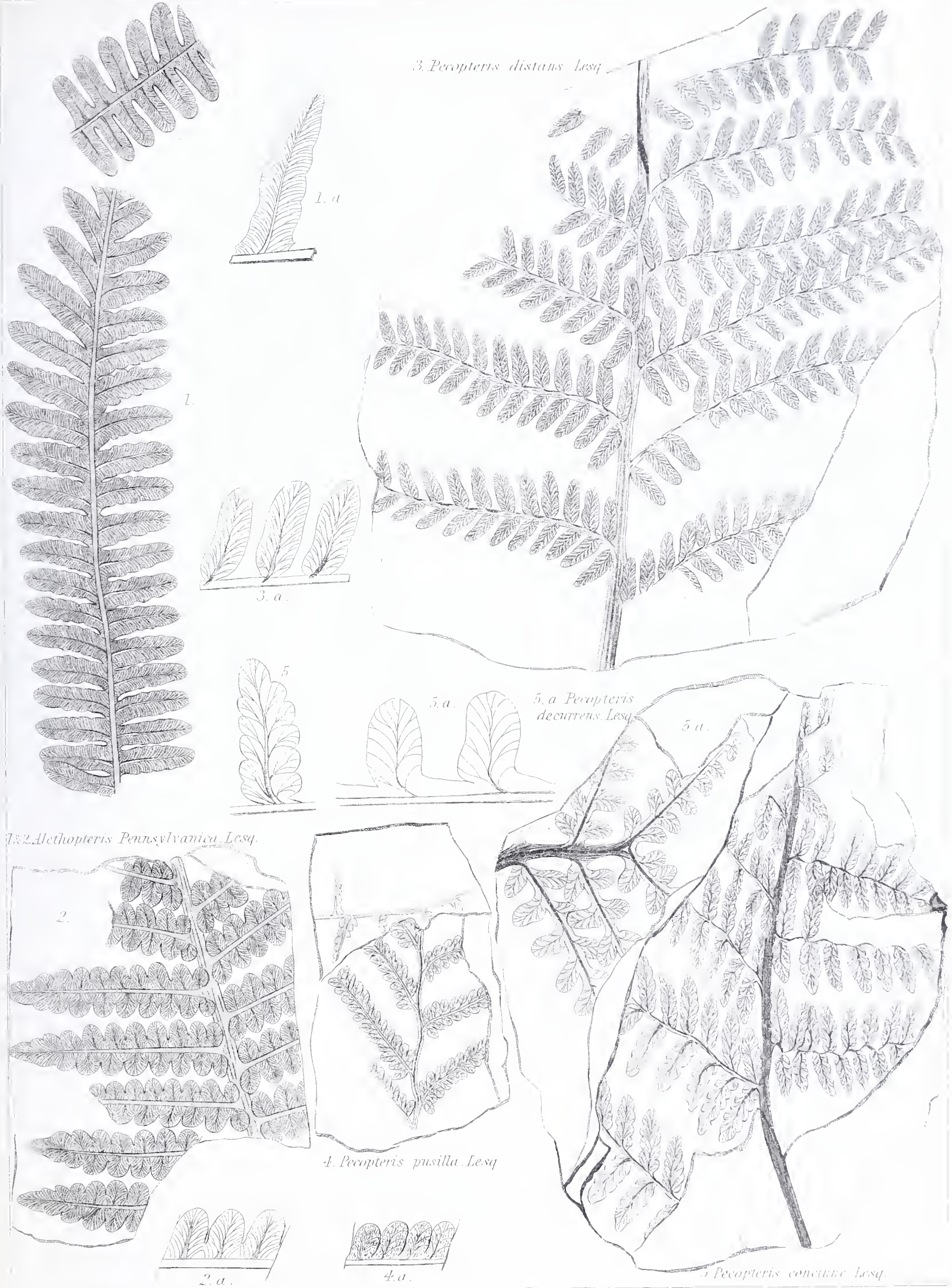
FOSSILS OF COAL FORMATION.

PLATE X


1.a.
1. Sphenopteris lesquereuxii, Newb.
2.
3. Sphenopteris squamosa, Lesq.

Eng'd by W. & A. K. Johnston, Edinburgh

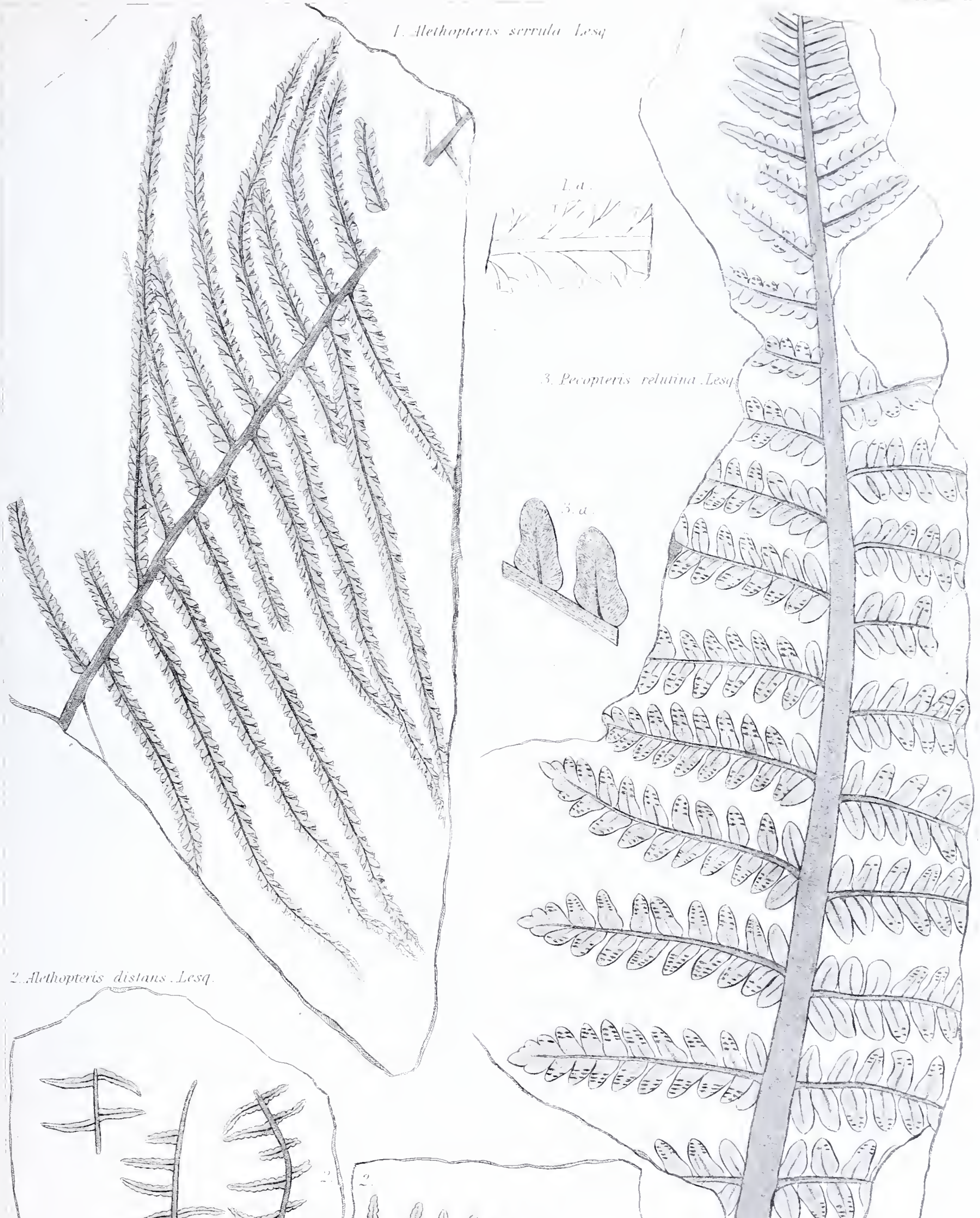
FOSSILS OF COAL FORMATION.


3. Pecopteris distans Lesq
1. a
1.
3. a.
5
5. a.
5. a Pecopteris decurrens. Lesq
5 a.
1 & 2. Alethopteris Pennsylvanica. Lesq.
2.
4. Pecopteris pusilla. Lesq
2. a.
4. a.
Pecopteris concinna Lesq.

Eng^{d} by W. [illegible] Johnston [illegible]urgh

FOSSILS OF COAL FORMATION.

PLATE XII.


1. Alethopteris serrula. Lesq.

1.a.

2. Alethopteris distans. Lesq.

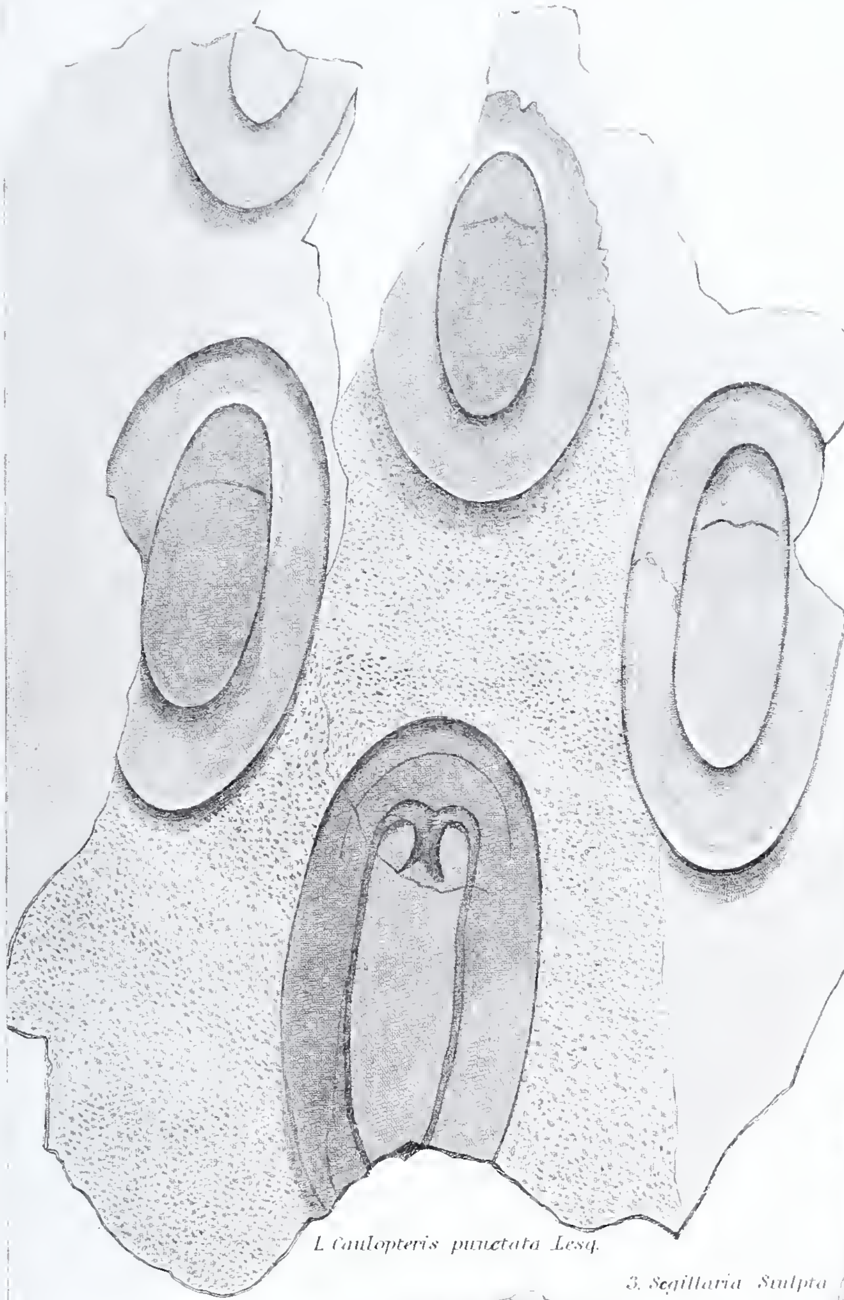
2.

2.

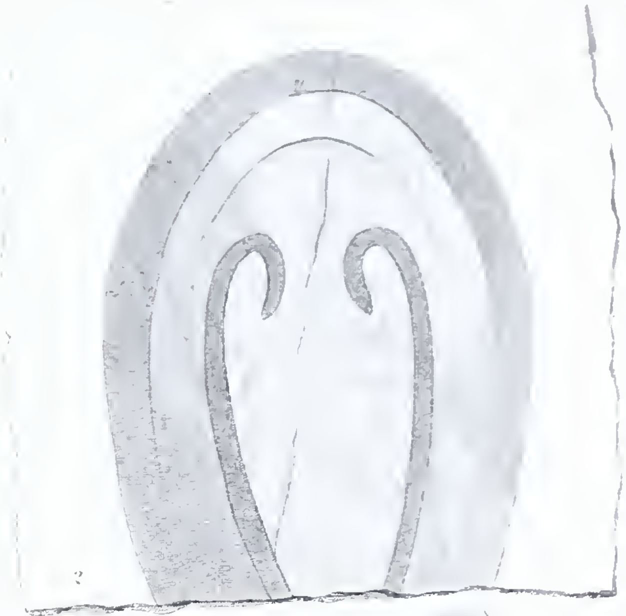
3. Pecopteris velutina. Lesq.

3.a.

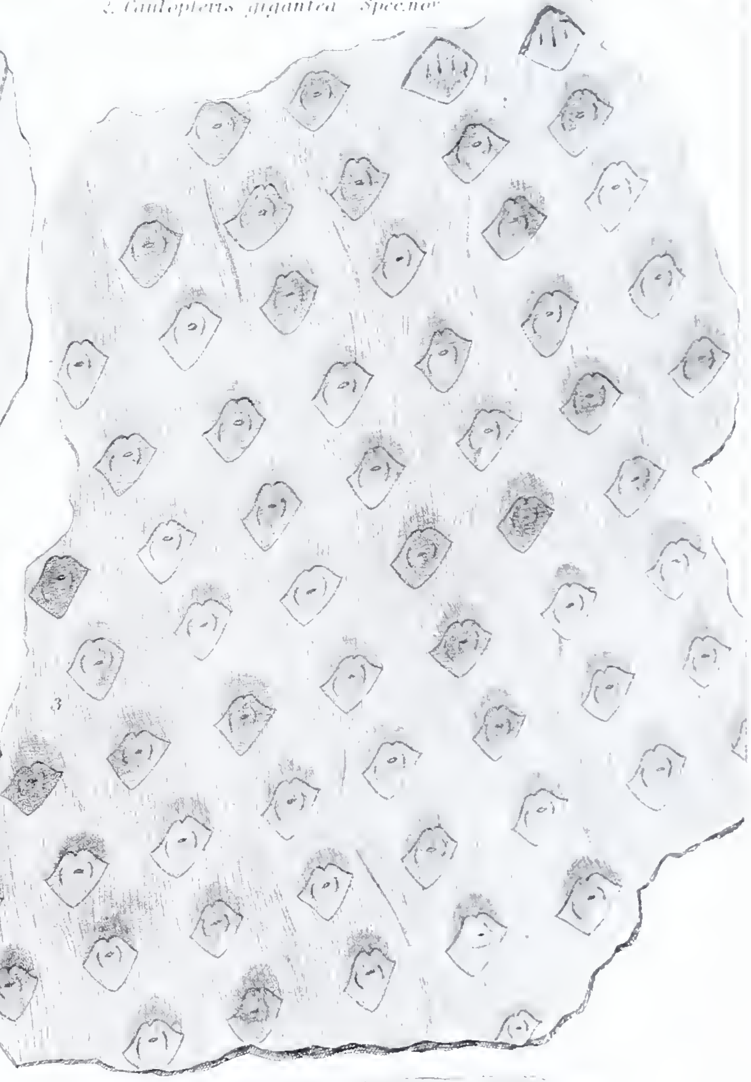
FOSSILS OF COAL FORMATION.



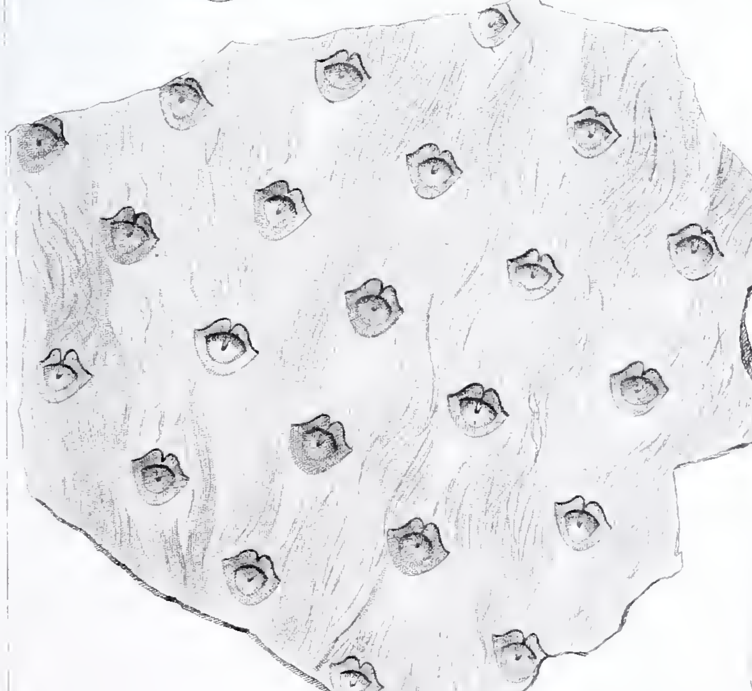
1. Caulopteris punctata Lesq.



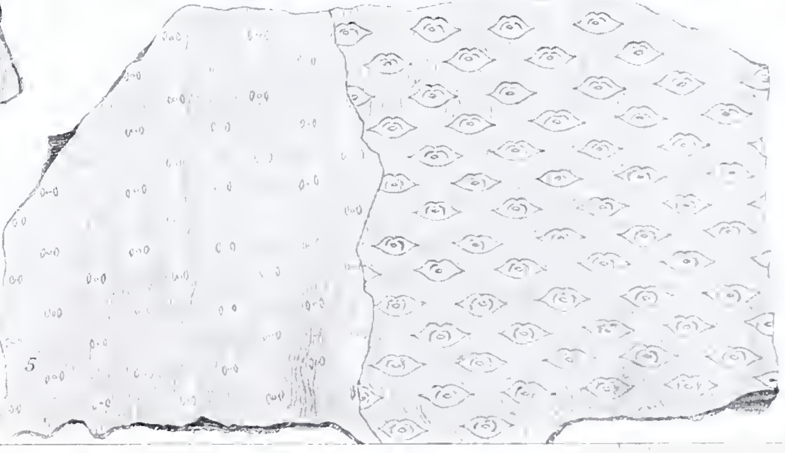
2. Caulopteris gigantea Spec.nov



3. Segillaria Sculpta



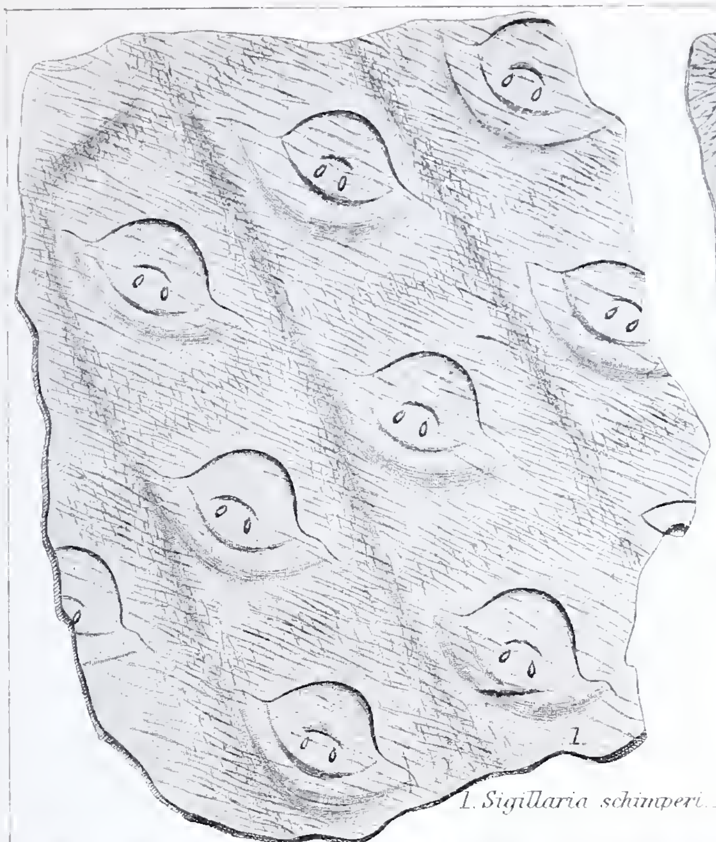
4 Sigillaria fissa Lesq.



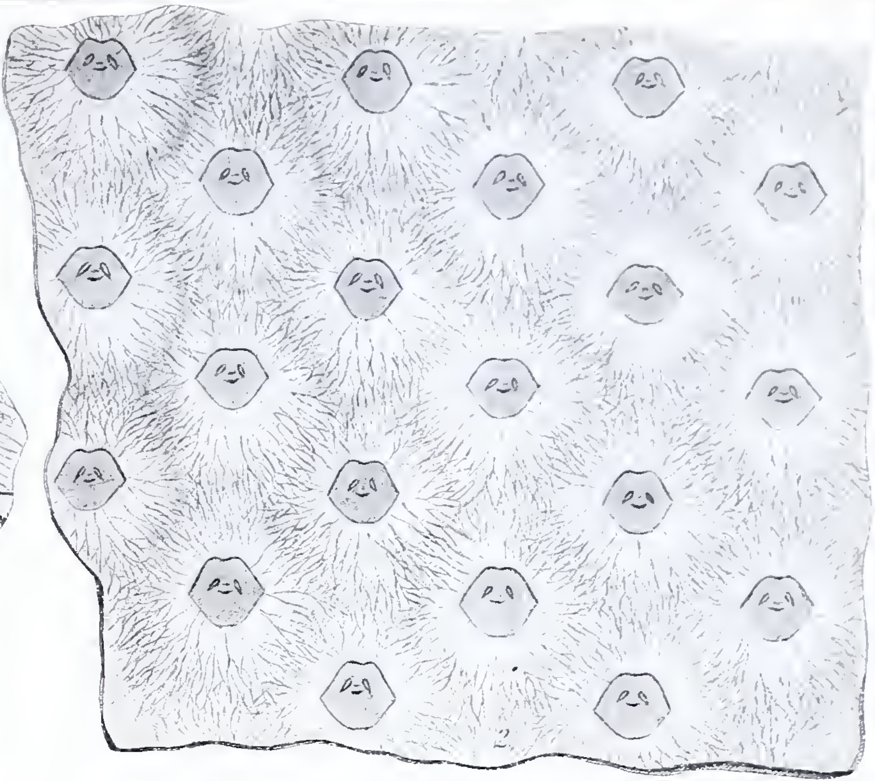
5 S. dilatata Lesq.

FOSSILS OF COAL FORMATION

PLATE XIV

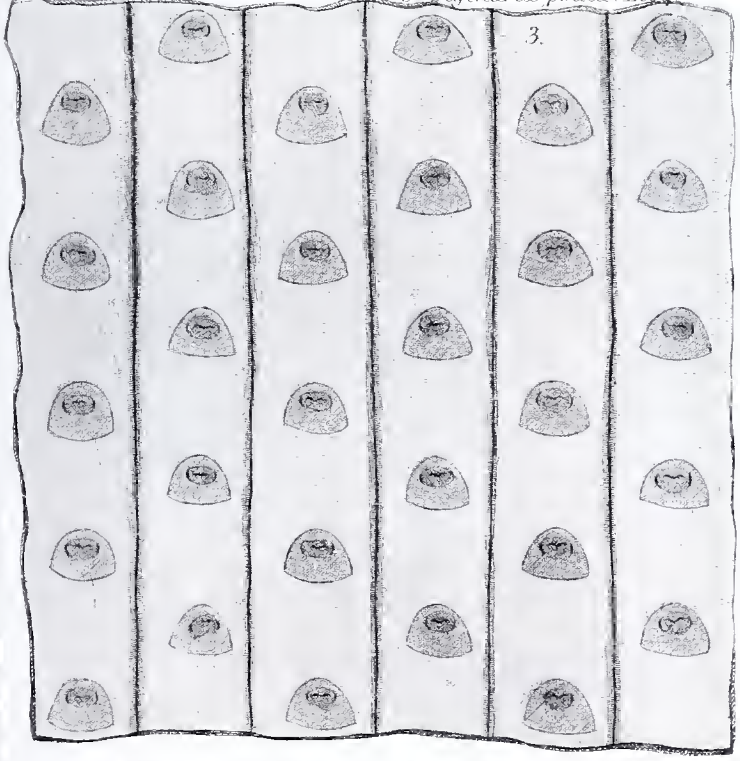


1. *Sigillaria schimperi. Lesq.*

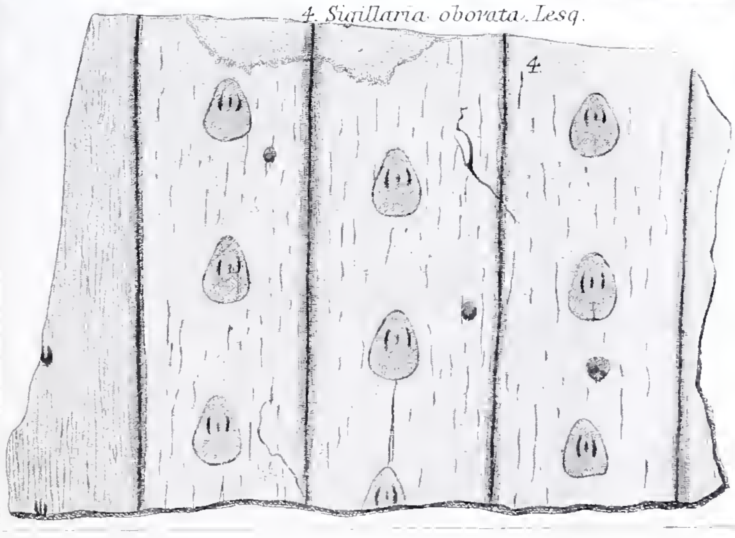


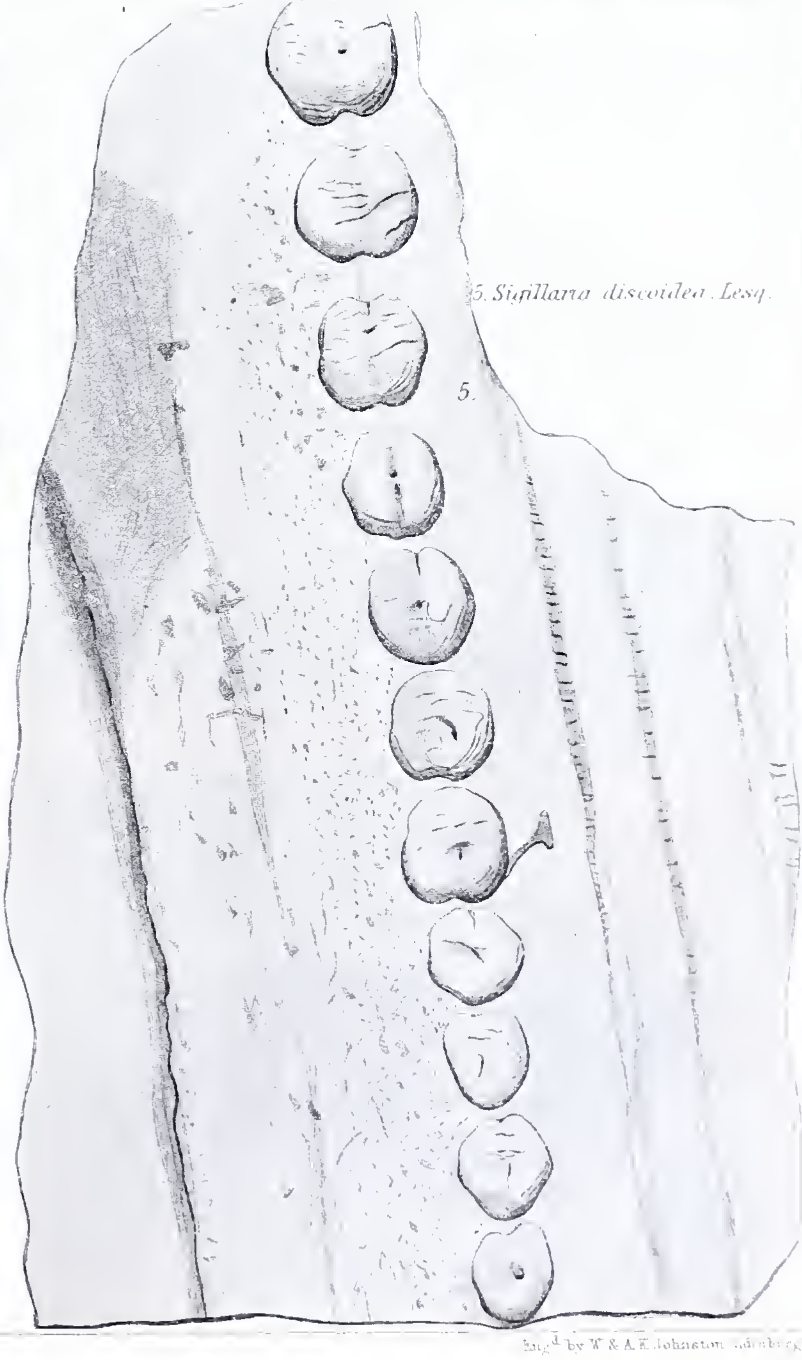
2. *Sigillaria stellata. Lesq.*

3. *Sigillaria polita. Lesq.*



4. *Sigillaria obovata. Lesq.*

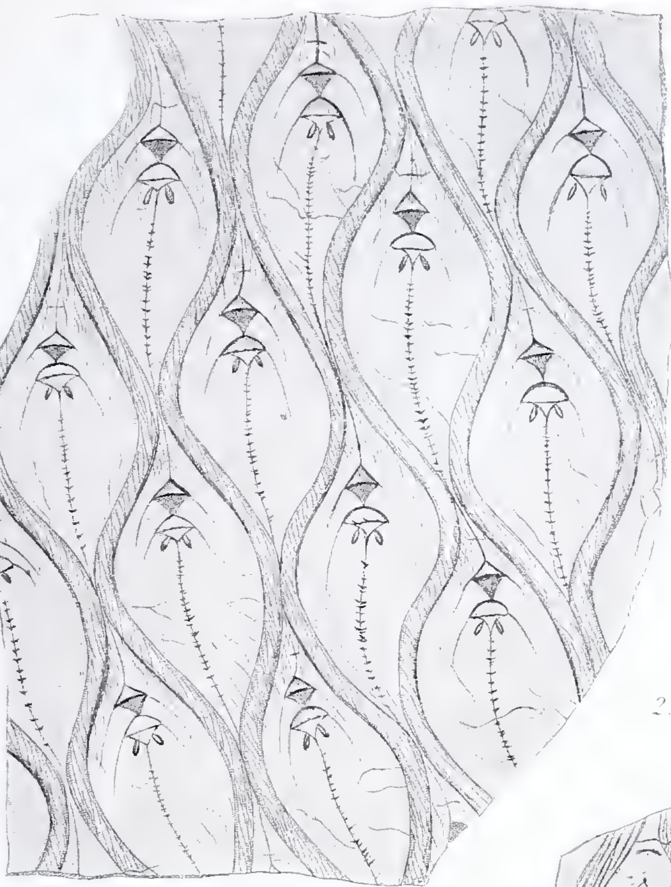




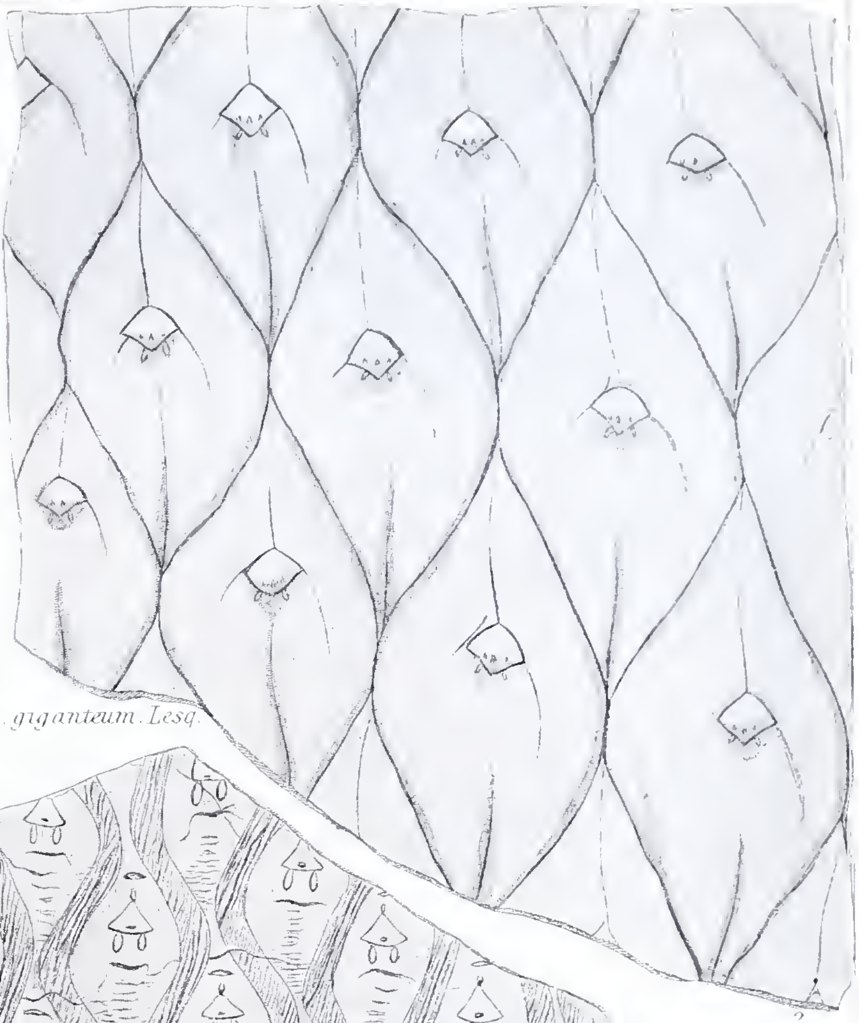
5. *Sigillaria discoidea. Lesq.*

Engd by W & A.K. Johnston, Edinburgh

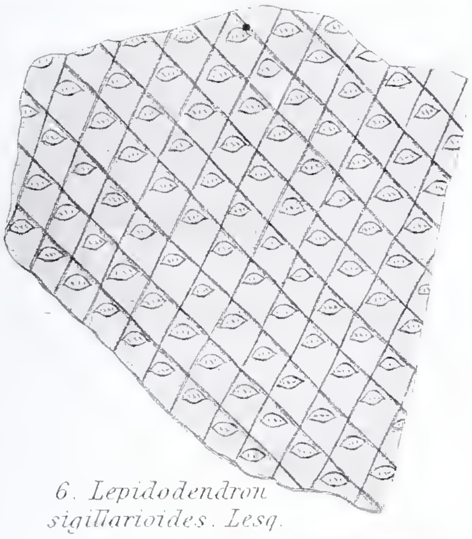
FOSSILS OF COAL FORMATION



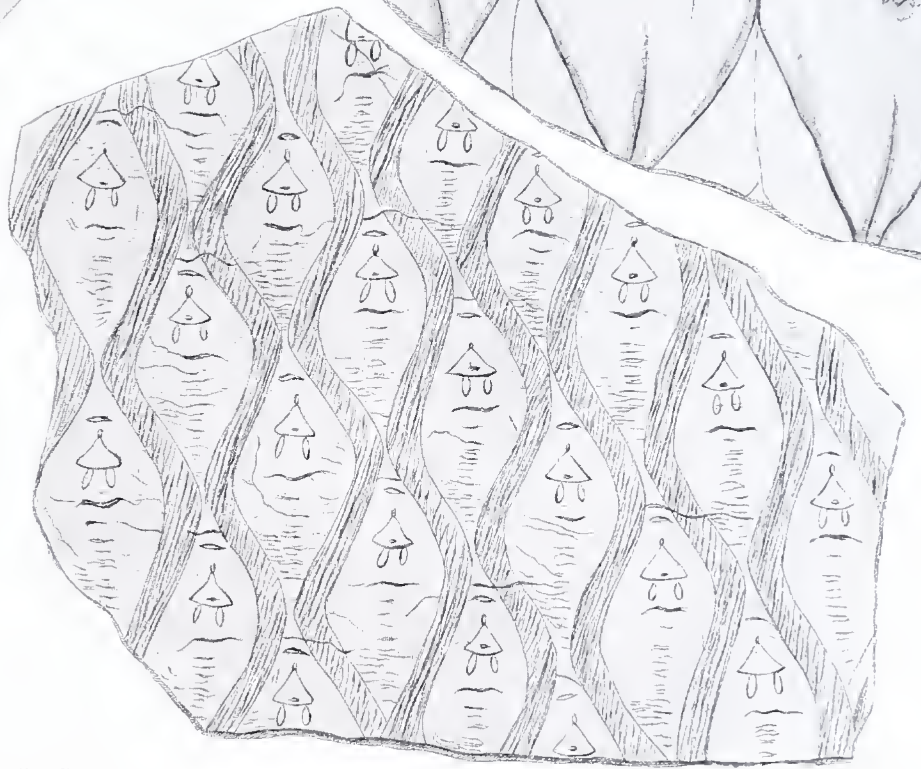
1. *Lepidodendron modulatum. Lesq.*



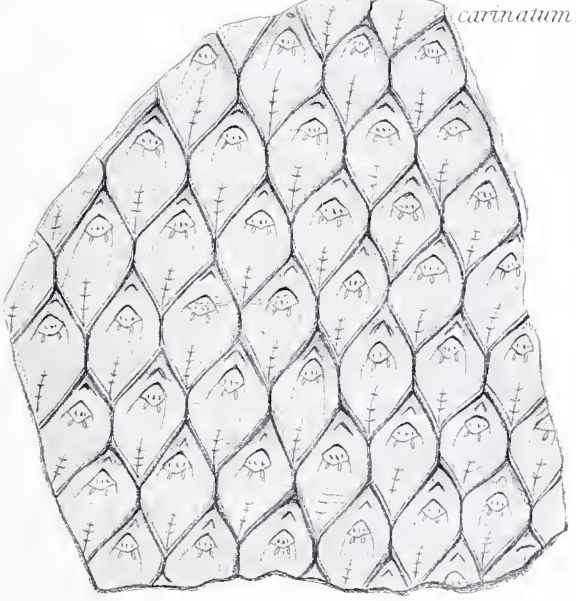
2. *L. giganteum. Lesq.*



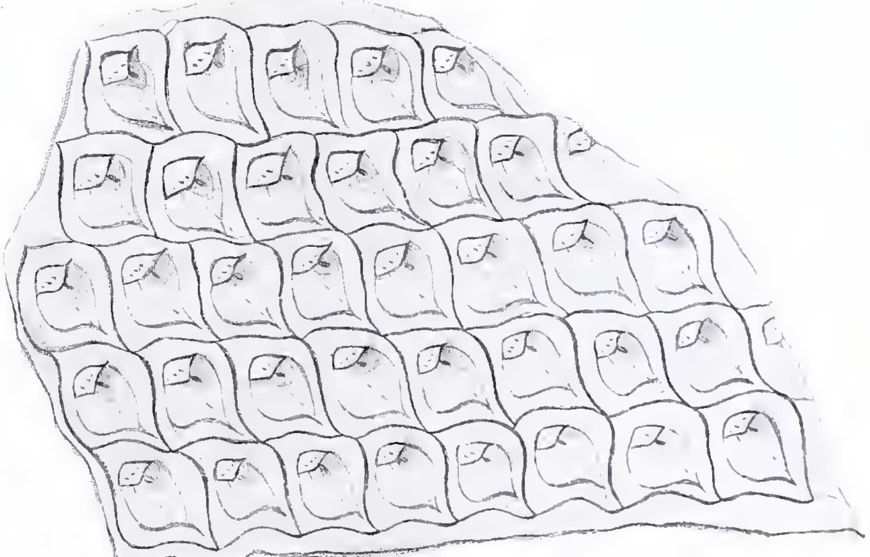
6. *Lepidodendron sigillarioides. Lesq.*



3. *Lepidodendron conicum. Lesq*



4. *Lepidodendron carinatum. Lesq.*

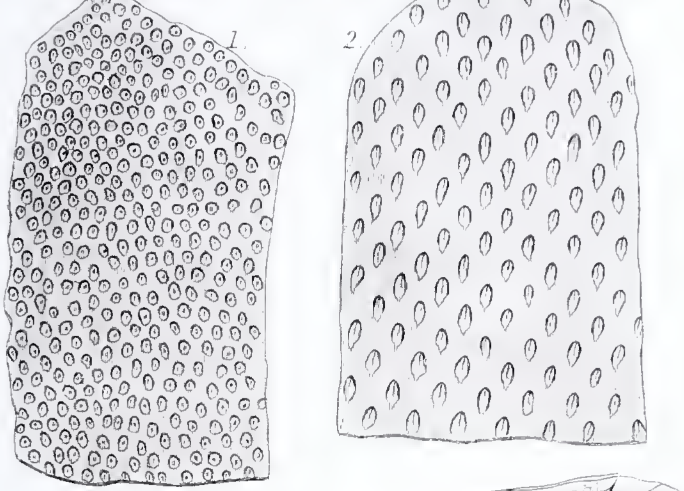


5. *Lepidodendron clypeatum. Lesq.*

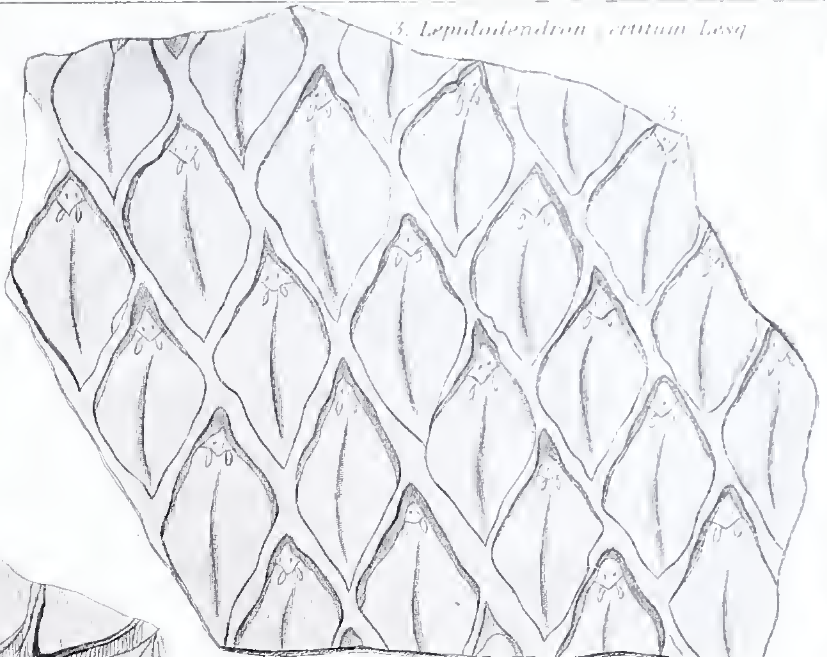
Eng^d by W. & A. K. Johnston, Edinburgh

FOSSILS OF COAL FORMATION.

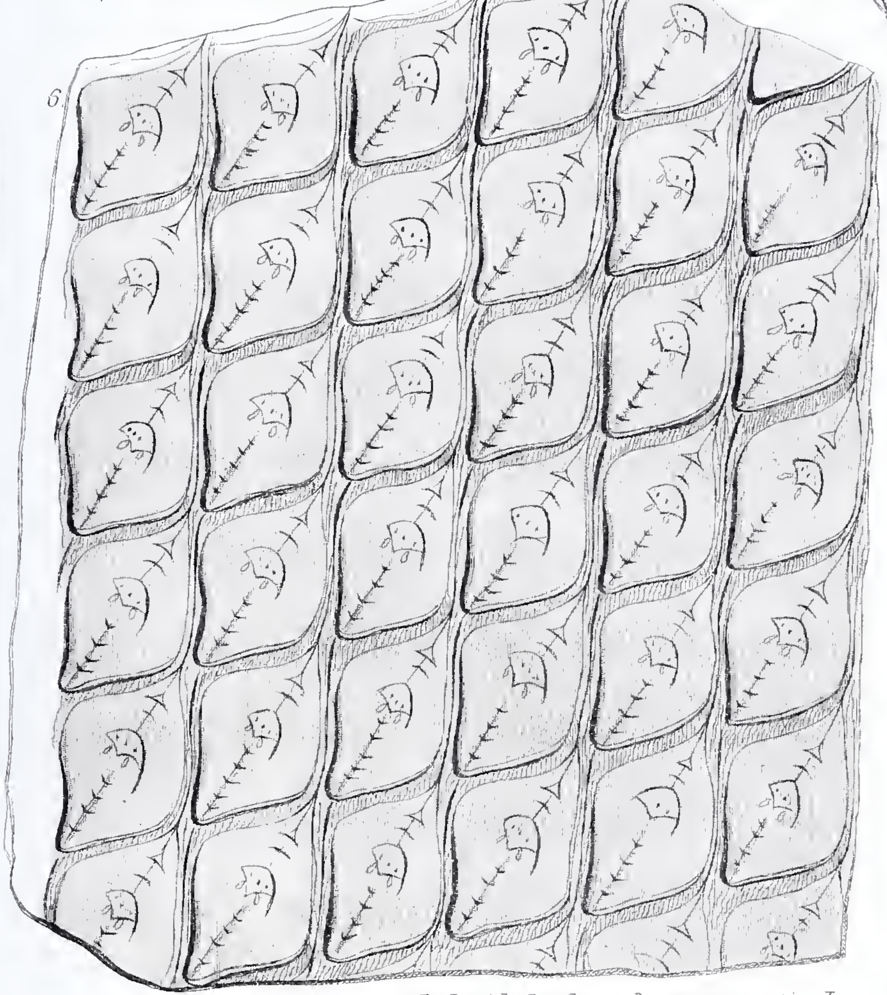
1.&2. *Stigmaria minuta. Lesq*

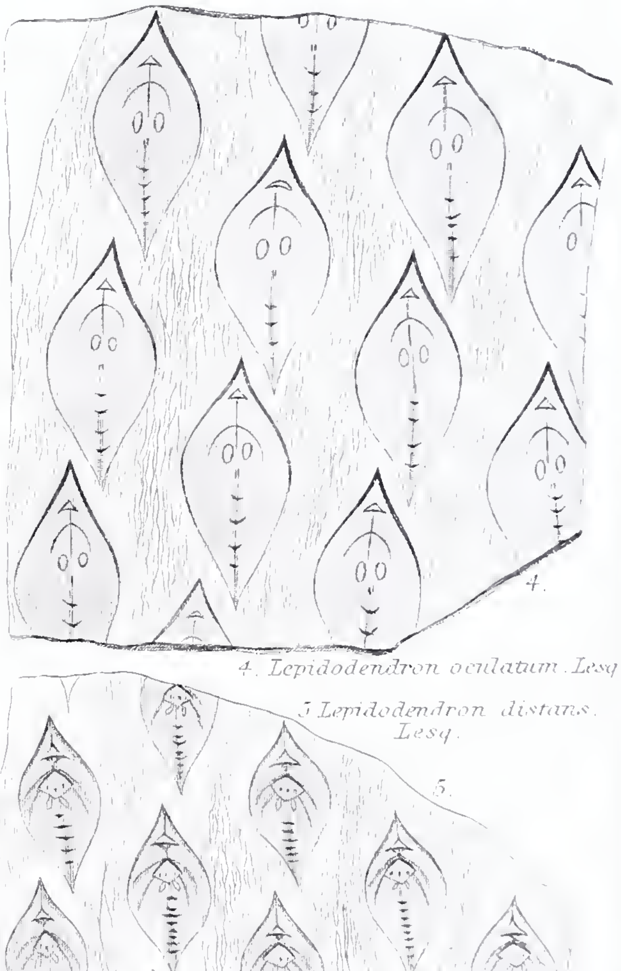


3. *Lepidodendron [illegible] Lesq*



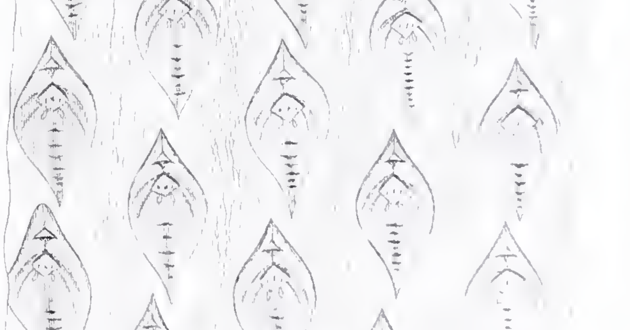
6. *Lepidodendron obtusum. Lesq.*



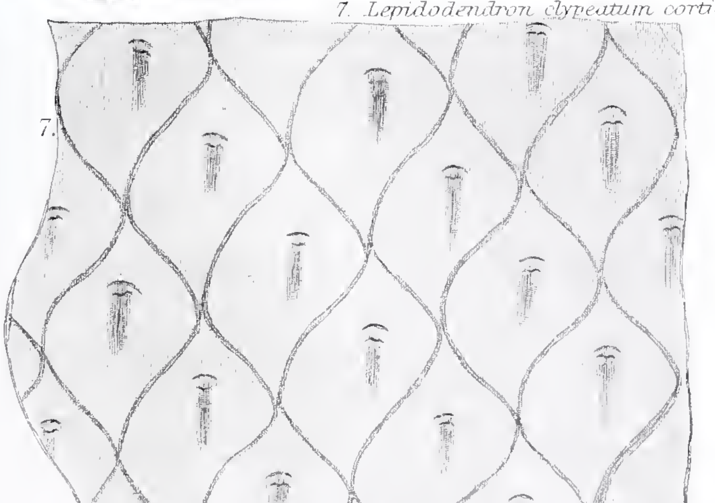


4. *Lepidodendron oculatum. Lesq*

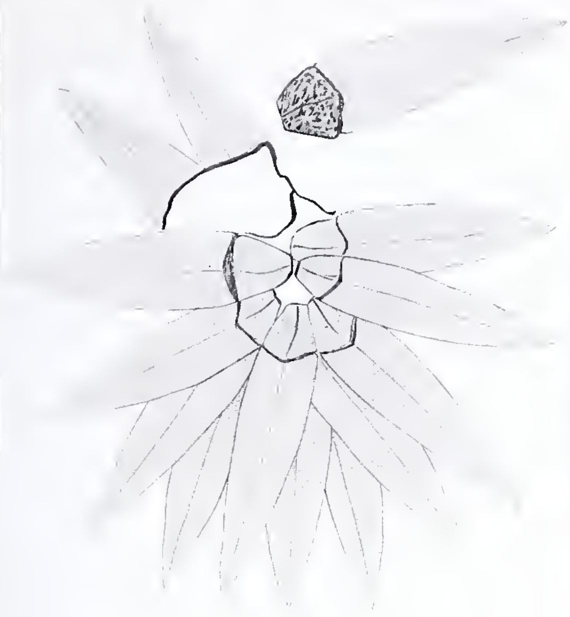
5. *Lepidodendron distans. Lesq.*

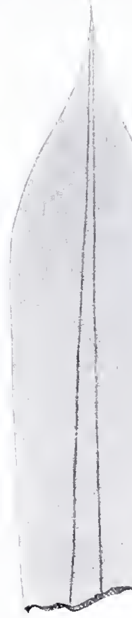


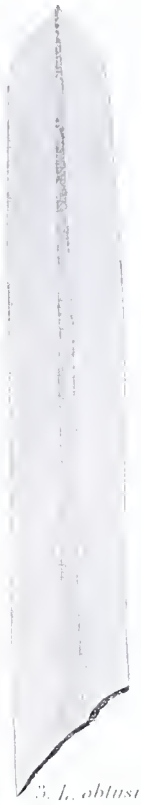
7. *Lepidodendron clypeatum cortic. Lesq.*



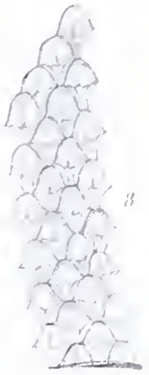
FOSSILS OF COAL FORMATION.


1. Lepidophyllum lanceolatum Br.!


2. L. acuminatum Lesq.


3. L. obtusum Lesq.

6. L. brevifolium Lesq

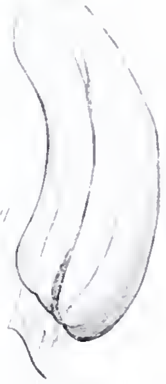

8

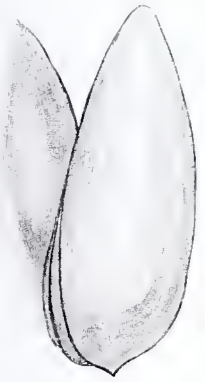
L. hastatum Lesq

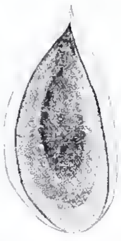
4. L. plicatum Lesq

9. Cardiocarpon plicatum Lesq

5. L. affine Lesq


10. Carpolithes bulides Lesq


11. Carpolithes distinctus Lesq.


12. Carpolithes platimarginatus Lesq.

13

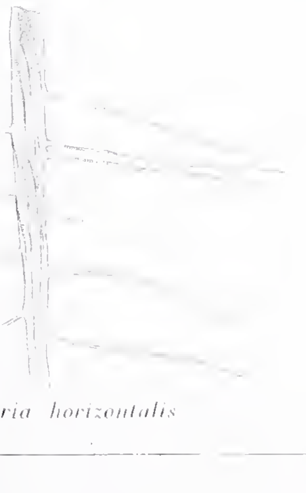
14

15

16

19. Pinnularia ficoides

18. Pinnularia pinnata

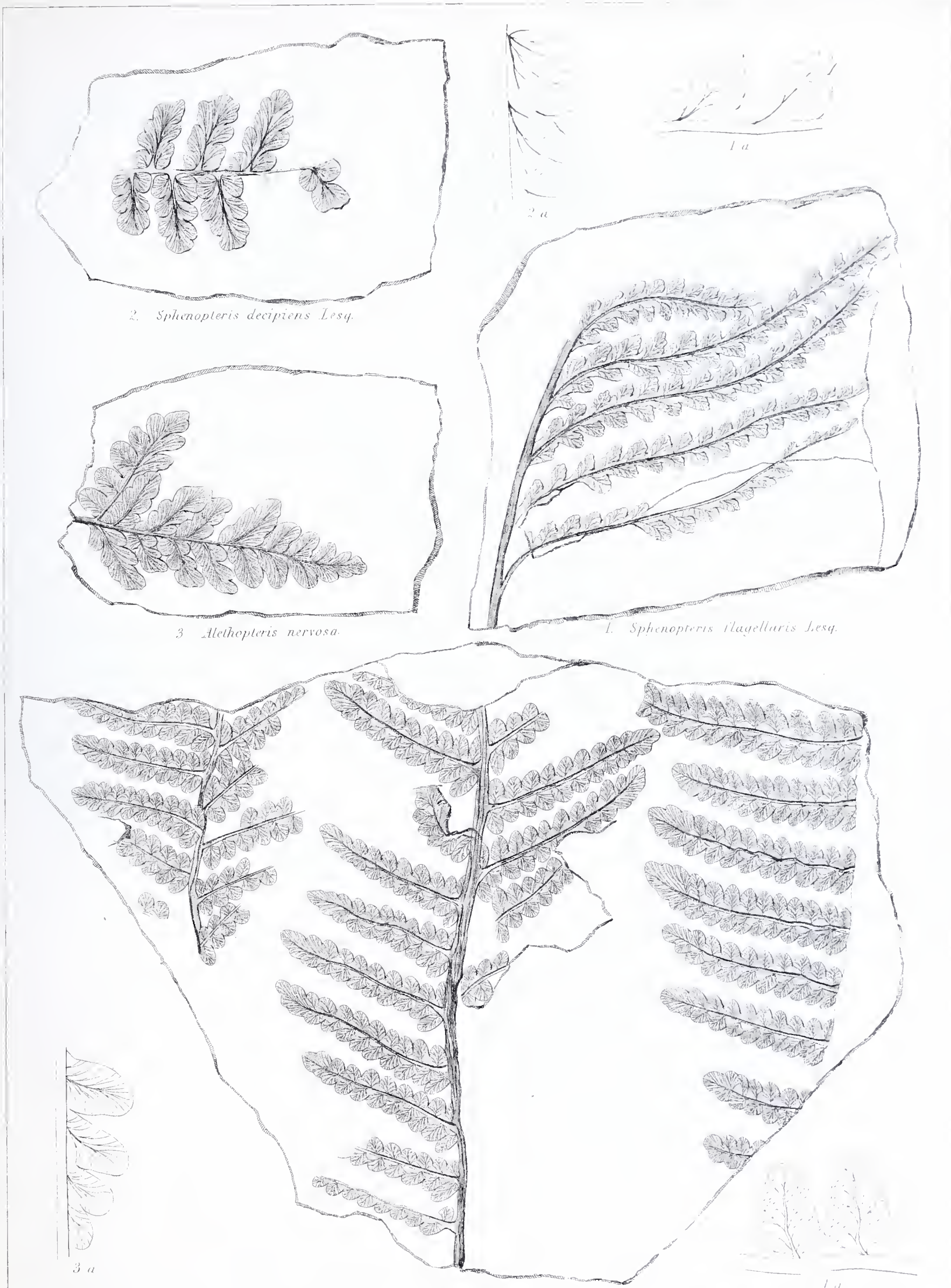

21. Pinnularia horizontalis

17

20. Pinnularia confervoides

22. Pinnularia capillacea

FOSSILS OF COAL FORMATION



2. *Sphenopteris decipiens. Lesq.*

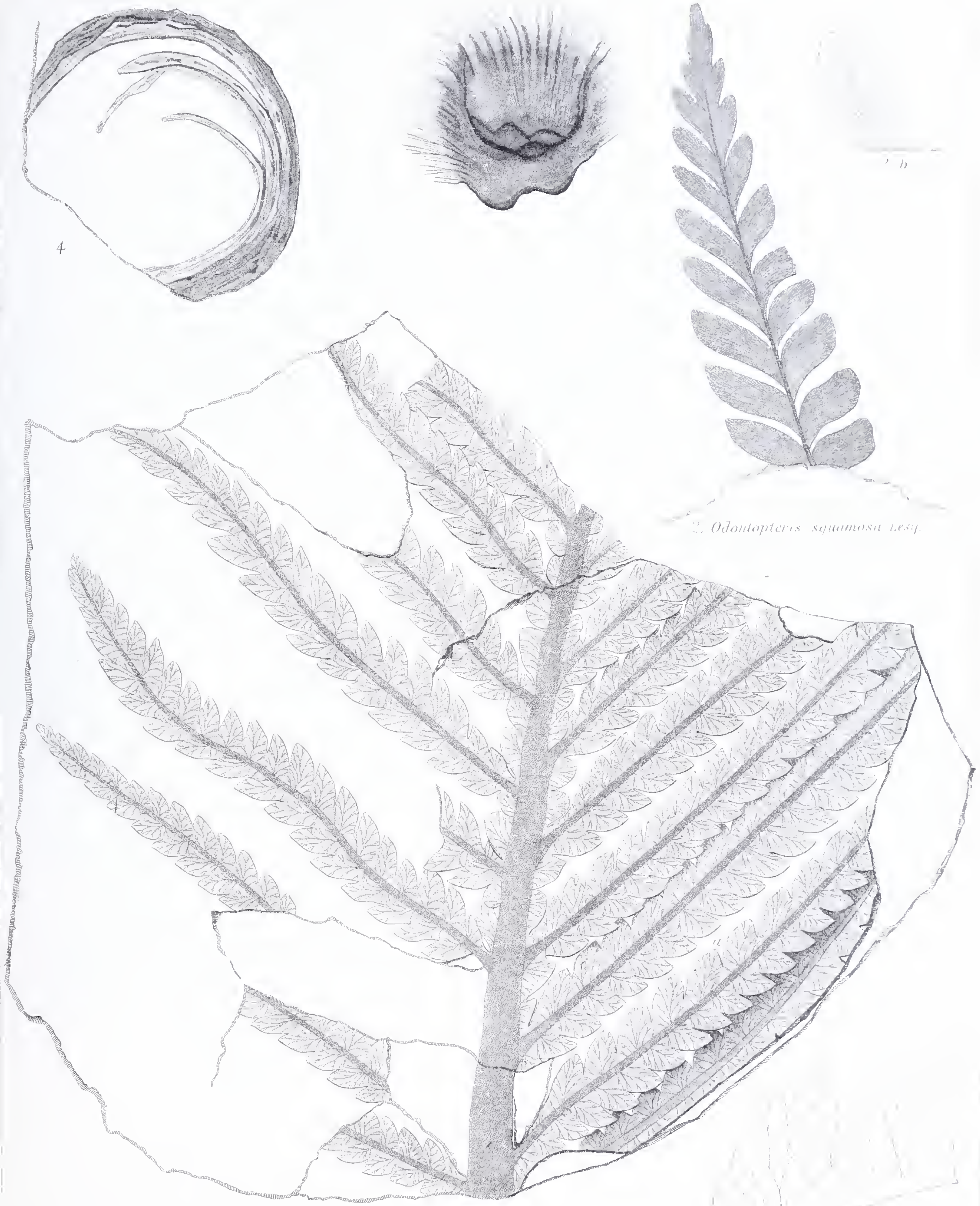
3. *Alethopteris nervosa.*

1. *Sphenopteris flagellaris. Lesq.*

4 *Pecopteris notata. Lesq.*

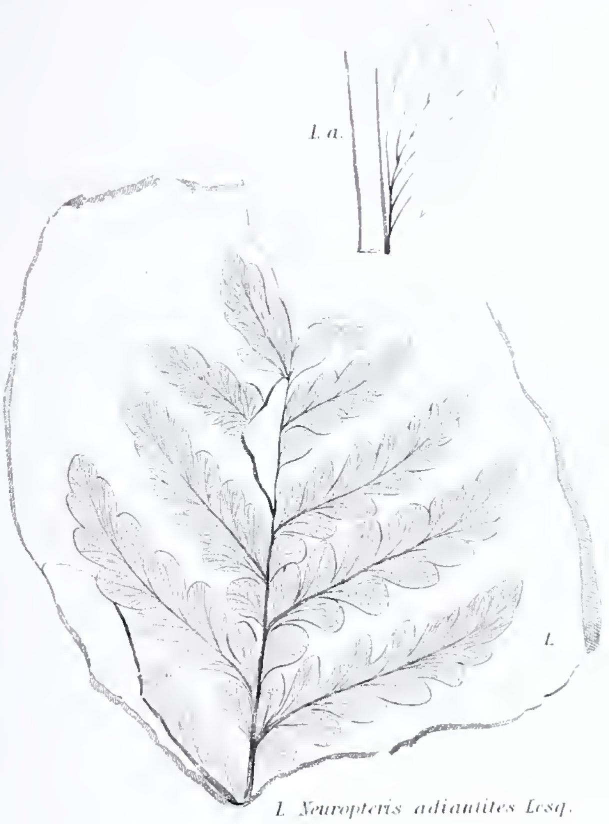
Engd by W & A.K.

FOSSILS OF COAL FORMATION

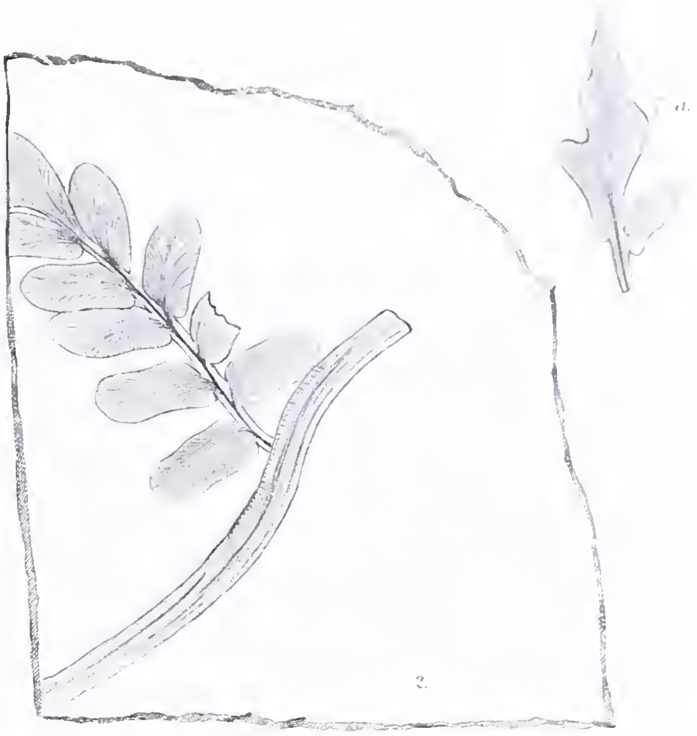

3 Cyclopteris laciniata Lesq
4
2 b
2. Odontopteris squamosa Lesq.
a
1. Neuropteris moorii Lesq
1 a

FOSSILS OF COAL FORMATION

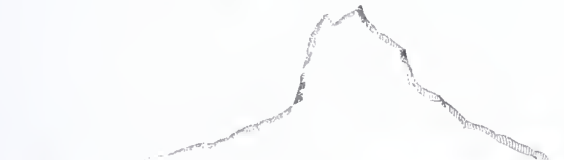
PLATE XX



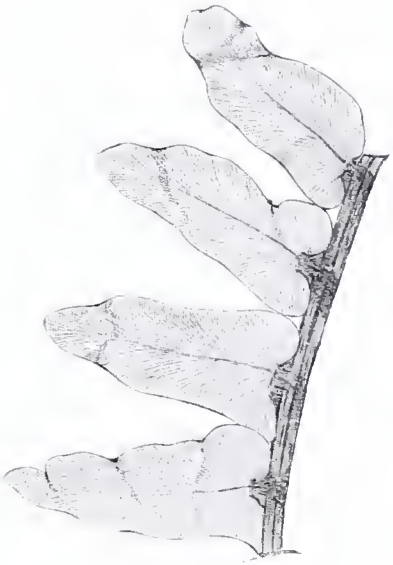
1. *Neuropteris adiantites Lesq.*



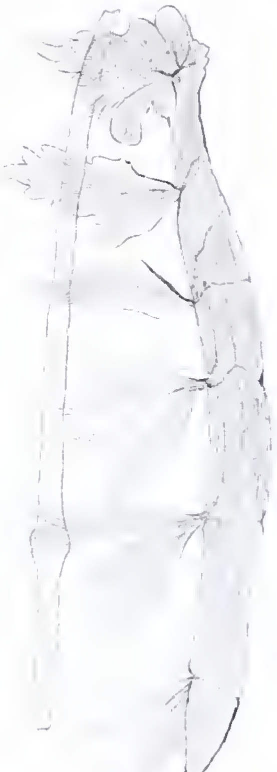
2. *Neuropteris delicatula Lesq.*



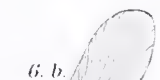
3. *Neuropteris Loschii Brong^t*

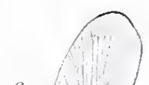


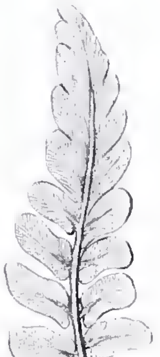
1. *Neuropteris plicata Sternb*



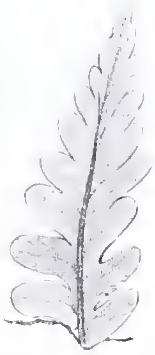
5. *Neuropteris Desorii Lesq.*







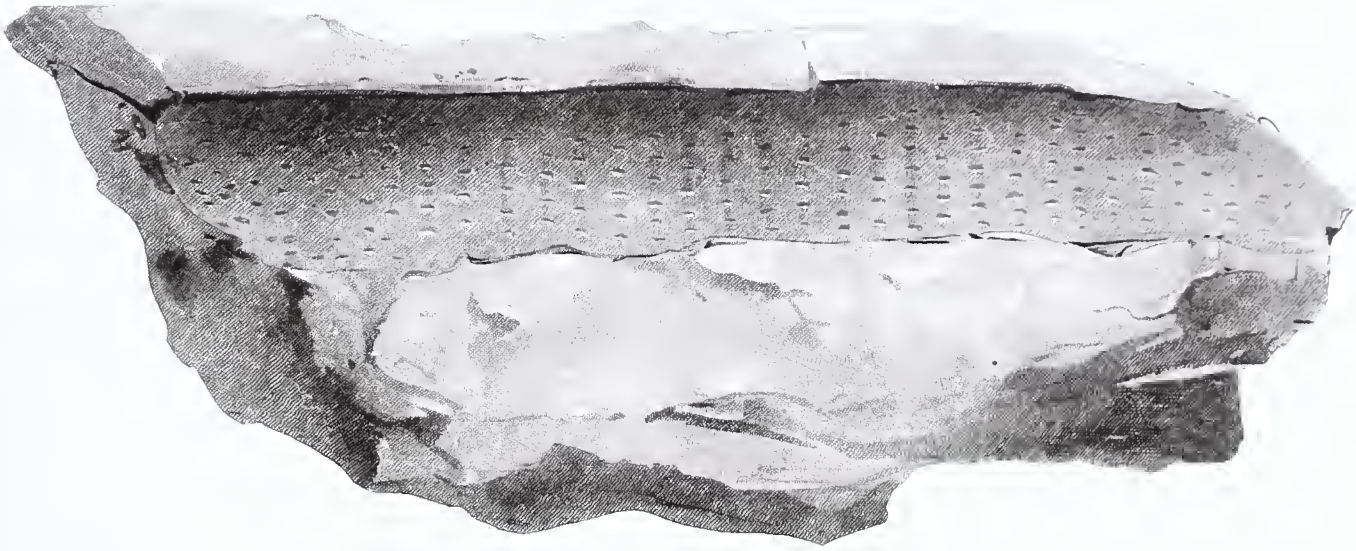
6. *Neuropteris Desorii Lesq.*



7. *Neuropteris Desorii Lesq.*

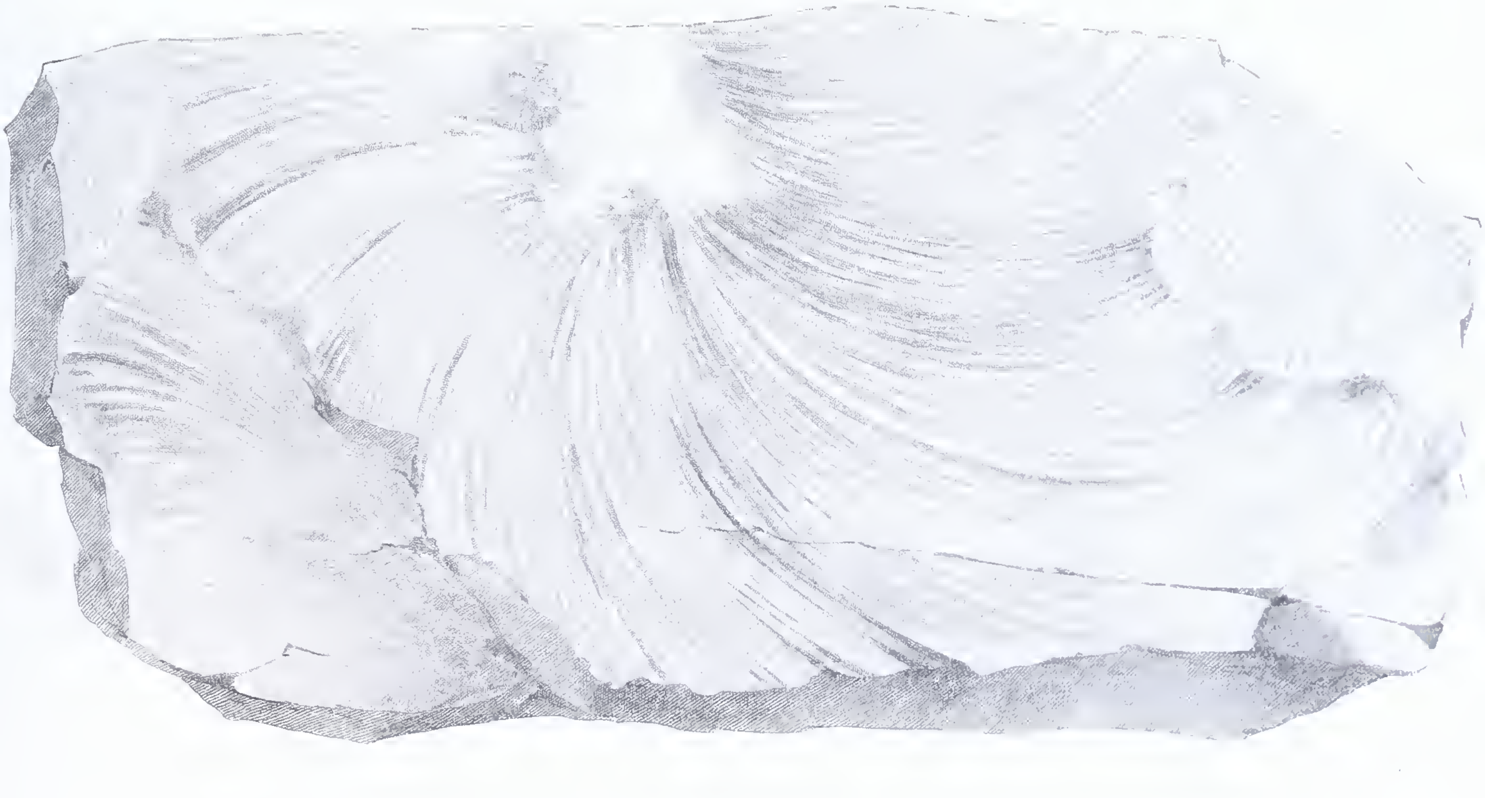
8. *Neuropteris Desorii Lesq.*

2



Lepidodendron Sp.? Vespertine Sandstone, Mauch Chunk.

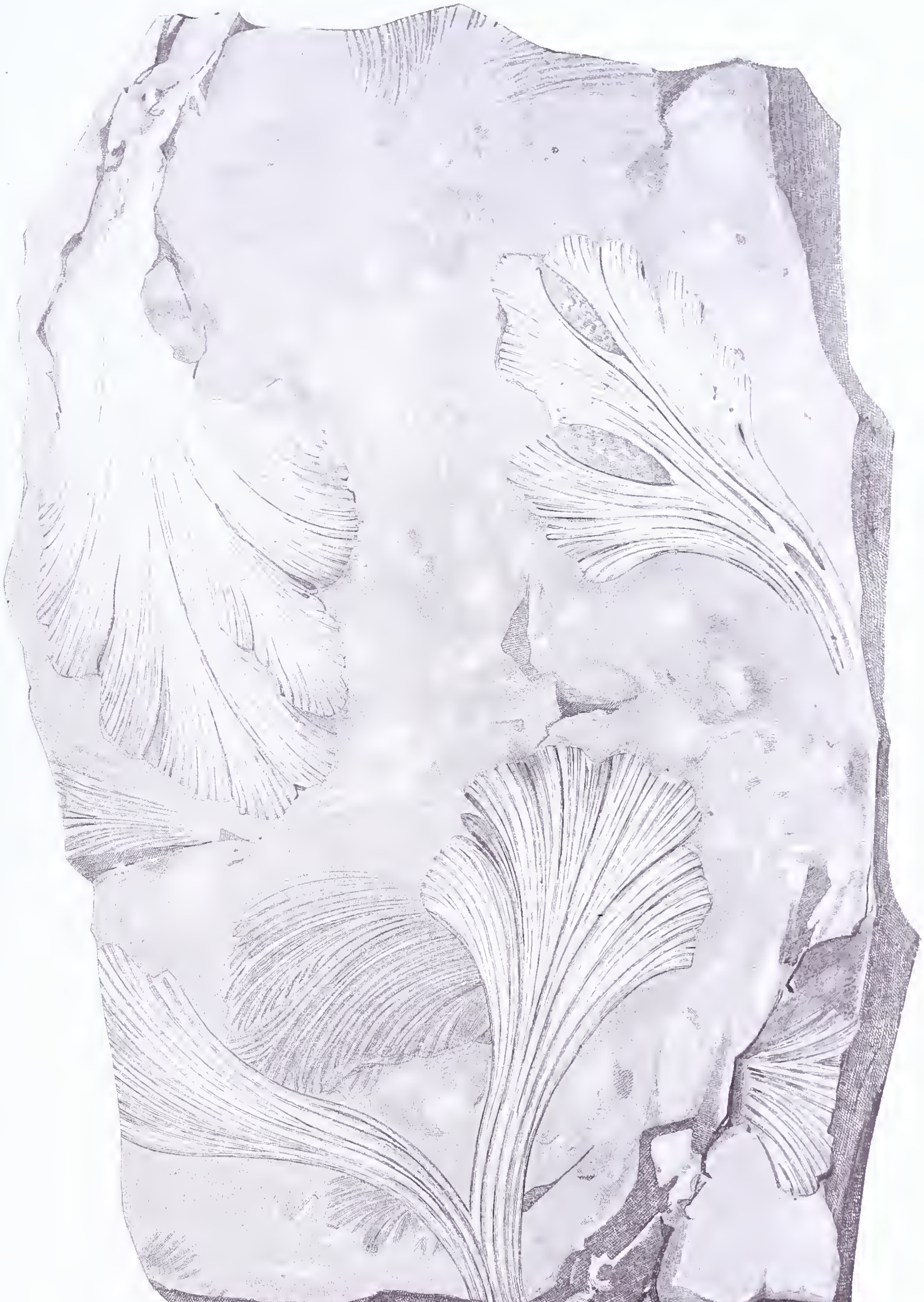
1



Filicoid resembling primordial frond of Platycerium

R.K. Greville Del'

FOSSIL PLANTS

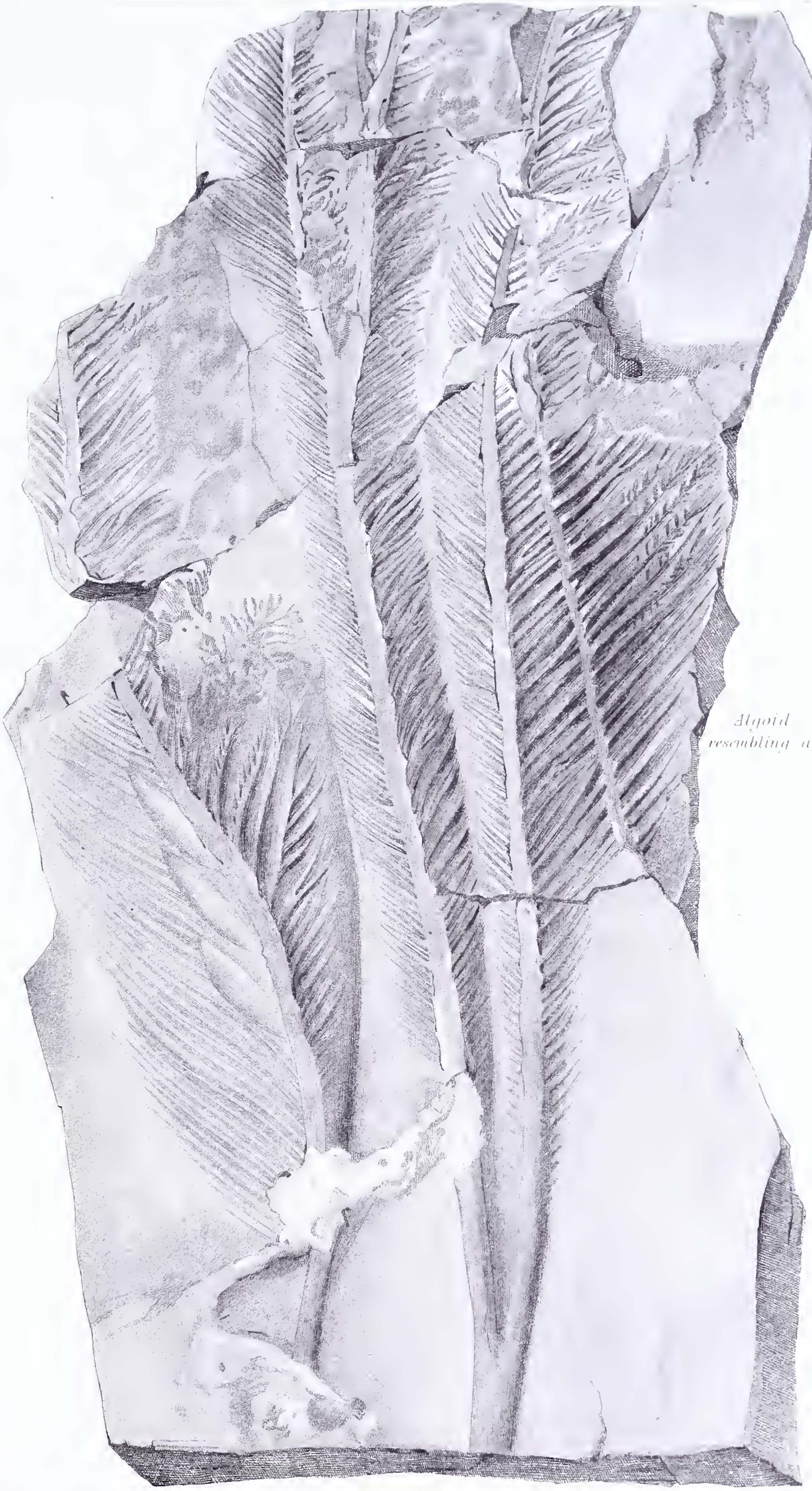


Leaf of a Gymnosperm Plant

R.E. Greville Delt

FOSSIL PLANT OF PONENT

PLATE XXIII



R. K. Greville Delt

[illegible]

FOSSIL PLANT OF UMBRAL

5168